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BY ARTHUR CONNELL, B.A. F.R.S.E.

FROM THE TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH

VOL. XXII.

Memorandum of the
Committee on the
Education of the
Deaf and Dumb

MEMOIR
ON THE
FRESH-WATER LIMESTONE OF BURDIEHOUSE,
IN THE NEIGHBOURHOOD OF EDINBURGH,
BELONGING TO THE
CARBONIFEROUS GROUP OF ROCKS;
WITH
SUPPLEMENTARY NOTES ON OTHER FRESH-WATER LIMESTONES.

By SAMUEL HIBBERT, M. D., F. R. S. Ed.

ALSO,

ANALYSIS
OF
COPROLITES, AND OTHER ORGANIC REMAINS,
IMBEDDED IN THE
LIMESTONE OF BURDIEHOUSE, NEAR EDINBURGH.

By ARTHUR CONNELL, Esq. F. R. S. Ed.

From the TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH,
VOL. XIII.

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ON THE
FRESH-WATER LIMESTONE OF BURDIEHOUSE
IN THE NEIGHBOURHOOD OF EDINBURGH
BELONGING TO THE
CARBONIFEROUS GROUP OF ROCKS

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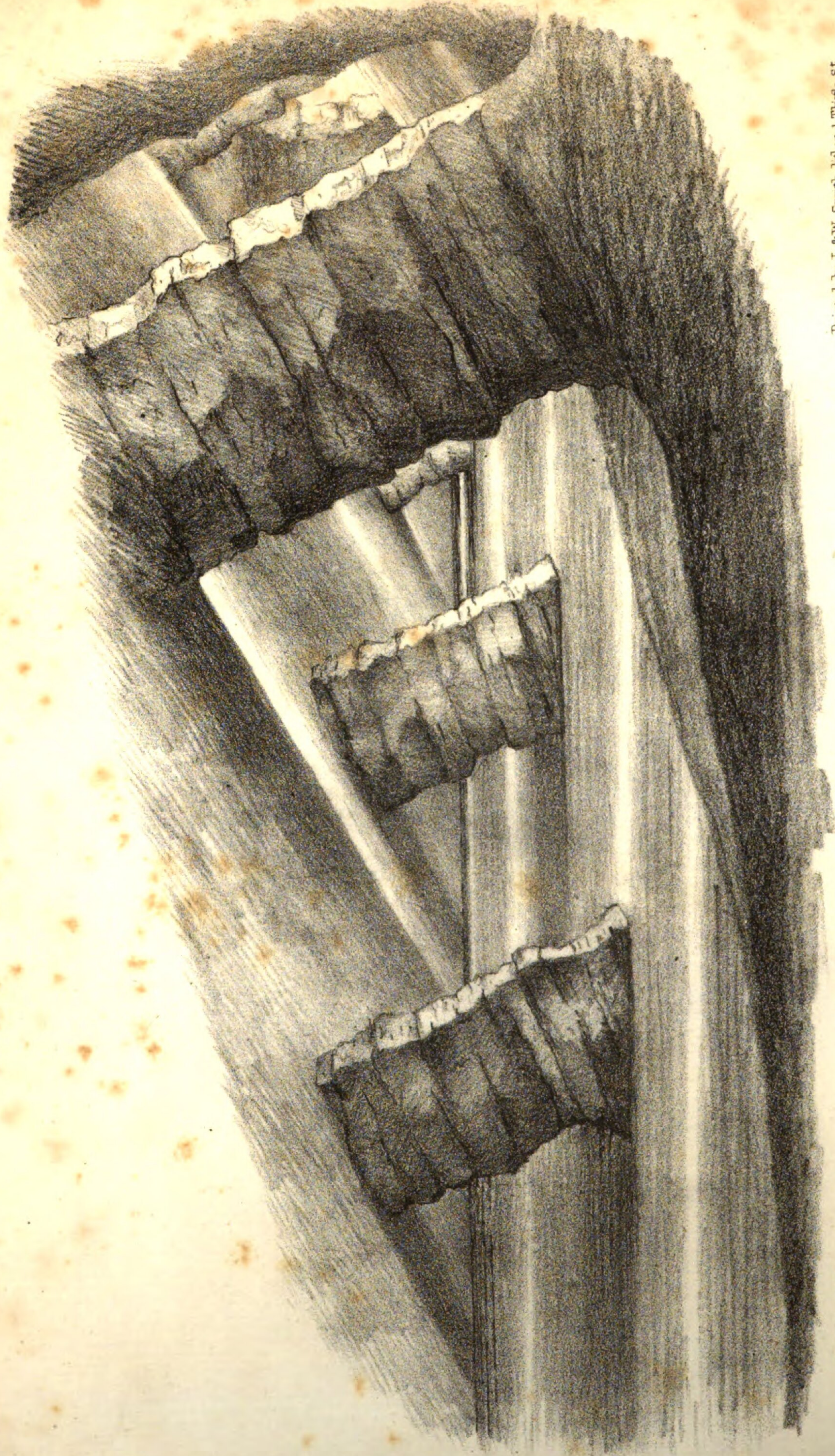
By Order of the Council,

JOHN ROBISON, Sec.

ANALYSIS
OF
CORALLITES AND OTHER ORGANIC REMAINS
IMBEDDED IN THE
LIMESTONE OF BURDIEHOUSE NEAR EDINBURGH
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FROM THE TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH
Vol. XIII.





T. Hibbert Del.

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THE OLD LIMESTONE QUARRY AT BURDIE HOUSE.

ON THE

FRESH-WATER LIMESTONE OF BURDIEHOUSE,

IN THE

NEIGHBOURHOOD OF EDINBURGH ;

WITH

SUPPLEMENTARY NOTES ON OTHER FRESH-WATER LIMESTONES.

BY

SAMUEL HIBBERT, M.D.,

FELLOW OF THE ROYAL SOCIETY OF EDINBURGH, OF THE GEOLOGICAL SOCIETIES OF
LONDON AND PARIS, &c. &c.

“There is one affair of moment concerning this primitive earth, that must first be stated and explained ; and that is, How it was watered—from what causes, and in what manner?”—“I confess there was nothing that gave so rude a stop to my thoughts, as concerning the rivers of the first earth,—how they rise, how they flowed, and how they ended. It seemed at first that we had wiped away at once the notion and whole doctrine of rivers ; we had turned the earth so smooth, that there was not an hill or rising for the head of a spring, nor any fall or descent for the course of a river.”

BURNET'S *Theory of the Earth*, book ii. chap. 5.

(Read, at various meetings of the Royal Society of Edinburgh, December 2, 1833,
February 17, April 21, and December 1, 1834.)

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REGIA
MONACENSIS.

NOTICE.

Nine Plates accompany this dissertation, which are described in page 114.
A supernumerary plate is given, Plate V. bis.

As frequent allusions are made in the course of these researches to the important geological indications afforded by the characteristic plant of Burdiehouse, the *SPHENOPTERIS AFFINIS* (see pages 5, 77, and 105), a drawing has been added, subsequently to the printing of this memoir, of the most perfect specimen of it which has yet come under my notice (see PLATE V. bis). It shews a linear structure finer than any which has yet been represented, with perhaps some little difference of venous arrangement.

I would also take this opportunity of correcting my omission in not thanking Dr SPITTAL of Edinburgh, for the loan of a curious fringed scale, drawn in Fig. 2. of Pl. X.

S. H.

PREFACE.

BEFORE the appearance of this memoir, no geological description has ever yet been published of a fresh-water limestone belonging to the carboniferous group of rocks; the existence of which has been even doubted.

The limestone of Burdiehouse contains no marine remains whatever.

The plants which it encloses are developed in the greatest possible abundance, and in a most beautiful state of preservation.

Entomostraca, analogous to the recent tenants of fresh-water marshes, so abound in the limestone as to occasionally impart to it an oolitic character.

Numerous small fish are enclosed in the limestone, comprising genera similar to such as are commonly found in coal-fields.

But the deposit is the most remarkable for the monsters which it contains. They are immense sauroid fish, forming the first connecting link between saurian and finny tribes. The existence of these animals during the carboniferous epoch, is a new and most important fact in geology, which for the first time has been brought to light.

Other extraordinary fish, the relics of which are entombed in the limestone, have been considered as approaching to the Cestracion of New Holland.

These details form the first portion of the present memoir.

In a second part of this memoir, the geological relations of the limestone of Burdiehouse are investigated.

The elevation of the great chain of the Grampians, as well as of much land north of the Tay, and of the ridge of grauwacke schist which extends from Berwickshire to Ayrshire and Galloway, has contributed to form the limits of an extensive basin, within which fluviatile and lacustrine deposits have been formed. These are indicated by the sandstones, shales, and fresh-water limestones belonging to the carboniferous group of the great Lowland valley of Scotland.

These strata, subsequently to their deposition, have undergone numerous fractures, in reference to which, the dislocated beds of the carboniferous

group of Mid-Lothian are considered as divisible into distinct systems, severally limited by prolonged and nearly parallel lines of fissure, which variously range between the limits of SSW. to NNE., and SW. to NE.

The investigation is then confined to the particular system of strata among which the calcareous deposit of Burdiehouse has been formed.

In this system, the fresh-water limestone developed at Burdiehouse and other localities, is regarded as nothing more than an individual member belonging to numerous alternating strata of sandstone, or argillaceous shale, which contain precisely the same organic remains, and which give similar evidence of a lacustrine or fluviatile origin.

These fresh-water beds are, in the next place, found to alternate with a limestone containing marine relics; and in other districts, even two or three alternations of the same kind may be traced. This curious fact, familiar to many geologists, is discussed in reference to the numerous oscillations which the crust of the globe has undergone during the carboniferous epoch. These movements have not only given rise to varied alternations of strata, but likewise to new and successive races of plants and animals.

The second part of the memoir concludes with a summary of the evidence relative to the origin of the limestone of Burdiehouse, in which this fresh-water deposit is compared with the estuarian limestone of Ashford in Derbyshire, and with the pelagic limestones of other localities.

In a Supplement, some few other fresh-water limestones in the vicinity of Edinburgh are noticed; but owing to the great length of this memoir, it has been impossible to do more than to state their general character. An outline is given of one of the most unique deposits of which Great Britain can boast, namely, that of Kirkton near Bathgate, which affords the indication of a deposit from thermal waters, coeval with the carboniferous epoch.

Lastly, by the kindness of Mr CONNELL, I am permitted to add his important "Analysis of Coprolites and other Organic Remains, imbedded in the Limestone of Burdiehouse."

MANOR PLACE, EDINBURGH,

30th January 1884.

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ON THE FRESH-WATER LIMESTONE OF BURDIEHOUSE.

INTRODUCTION.

I PROPOSE in this memoir to methodically connect several desultory notices, which I had occasion to read during the last session of the Royal Society's meetings, relative to the Limestones of fresh-water origin in the neighbourhood of Edinburgh, belonging to the carboniferous group of rocks, and to the organic remains which they contain.

Hitherto, the limestones belonging to this older class of deposits have been considered as exclusively of marine origin. I had long since, however, been prepared to expect that a limestone of a fluviatile or fresh-water origin would, some time or other, be proved to exist. For, in judging from analogy, it would be unreasonable to presume, that, when fresh-water limestones appear in the rocks of every later epoch, they should meet with an exclusion in the carboniferous group. In entertaining, therefore, less confined views, I was not at all surprised to find them confirmed in a limestone near Edinburgh, which lately came under my examination,—I allude to that of Burdiehouse. It enclosed none of the marine shells, corallines, or encrinites to be found in the other limestones of the vicinity, but contained in the place of them, and in the greatest possible abundance, the various plants observable in our coal-fields. I also procured from it

specimens of fish allied to such as are obtained from beds associated with coal. These facts indicated to me that I had at length found a fresh-water limestone belonging to the carboniferous group of rocks.

This fresh-water formation, which has formed the object of my research, is referable to the lower series of beds belonging to the carboniferous system. In describing it, the FIRST PART of the present memoir will be confined to a geological description of the limestone of Burdiehouse, in reference solely to the vegetable and animal remains which it encloses ;—a SECOND PART will point out the relations of this limestone to both older and newer rocks ;—while a SUPPLEMENT will include notices of certain other limestones of a similar description, occurring in the vicinity of Edinburgh.

PART I.

THE FRESH-WATER LIMESTONE OF BURDIEHOUSE CONSIDERED IN REFERENCE TO THE VEGETABLE AND ANIMAL REMAINS WHICH IT ENCLOSES.

No geological description whatever having been hitherto given of this limestone, which, until it had been examined by myself, and its high interest explained to the Royal Society of Edinburgh, had been almost unknown, even by name, I must, upon this account, consider myself as having entered upon a ground perfectly unbeaten, which I tread with diffidence.

This bed of limestone is quarried, with much profit, for the purpose of burning. It is to be seen about four miles to the south of Edinburgh, on the Peebles road, close to the village known by the name of Burdiehouse, which is a corruption of Bourdeaux House.

NOTES.

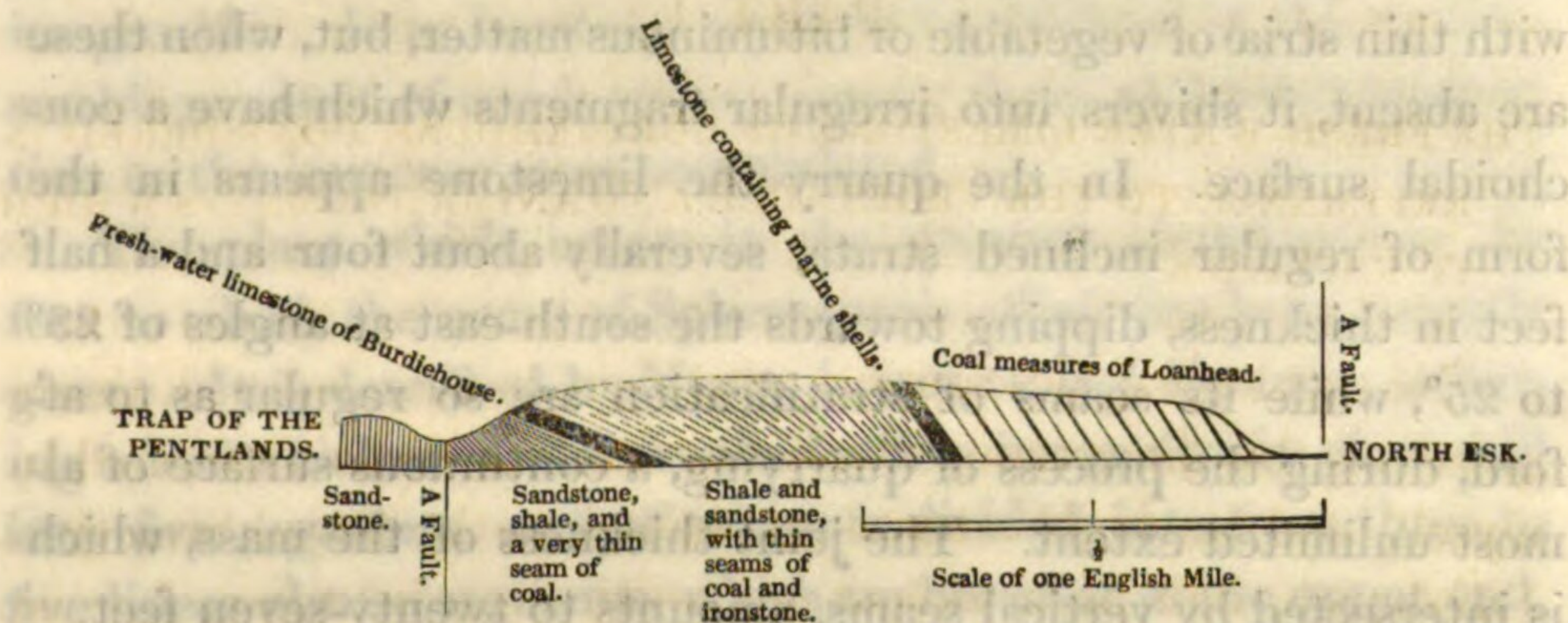
In the Transactions of the Society of Antiquaries of Scotland, vol. i. p. 311, some little account is given of this village by the Rev. THOMAS WHITE, in his

description of the Parish of Libberton. He states that "north from Straiton is the village of Bordeaux, so called, perhaps, by some of the French who attended Queen Mary in her return home to Scotland in 1561, and who happened to take up their residence here."

It is probable that the name of *Bourdeaux House* was derived from an ancient mansion said to have once stood in the immediate neighbourhood of the village of Bordeaux, which was built about the time of the unfortunate Mary, and was inhabited by the French who came in her train.

SECTION I.—THE GEOLOGICAL PLACE ASSIGNABLE TO THE LIMESTONE OF BURDIEHOUSE.

The limestone of Burdiehouse may be referred to the lower beds of the carboniferous system, as is evident from the following section :



In judging from the foregoing section, the place which the fresh-water limestone holds in the carboniferous system is sufficiently evident. It maintains a position far beneath a limestone containing marine shells, which is continuous with the well known Gilmerton bed, and still farther beneath the rich coal seams of Loanhead. But I suspend any farther particulars relative to the strata either below or above this bed of limestone, which will be better appreciated after it has been itself described

in detail. I may merely remark, at present, that it is a bed in which some of the earliest vegetable and animal tribes incidental to the carboniferous epoch are entombed.

SECTION II.—MINERALOGICAL CHARACTER OF THE LIMESTONE.

The limestone of Burdiehouse admits of various tints. It often acquires its bluish-grey or blackish-grey colour from the bituminous or vegetable matter which is so abundantly diffused through it. Other tints approach to those of a clove-brown, or even of a lavender-purple. In its composition it shews very rarely any crystalline texture, such as is observable in the mountain limestone of neighbouring quarries; but, on the contrary, while it is of a dull earthy aspect, its consistence is very compact. The hardness of this limestone is considerable. In its fracture it sometimes breaks into a slaty form, particularly when it is alternated with thin striæ of vegetable or bituminous matter, but, when these are absent, it shivers into irregular fragments which have a conchoidal surface. In the quarry the limestone appears in the form of regular inclined strata, severally about four and a half feet in thickness, dipping towards the south-east at angles of 23° to 25° , while its seams of stratification are so regular as to afford, during the process of quarrying, a continuous surface of almost unlimited extent. The joint thickness of the mass, which is intersected by vertical seams, amounts to twenty-seven feet.

The Burdiehouse limestone seems to be tolerably pure, admitting in its composition few extraneous substances except those which have a vegetable or animal origin; for which reason, it is wrought for the kiln with much advantage. It is traversed in various places by small veins of calcareous spar. It contains some little siliceous matter, and the sulphuret of iron may be occasionally found interposed between its layers.

But this rock is the most remarkable for the vegetable and animal remains contained by it, which concur in awarding to it, not a marine but a fresh-water origin; and hence, the great diffe-

rence of character which it will be found to exhibit when compared with the common mountain limestone of geologists.

SECTION III.—THE FOSSIL FLORA OF THE LIMESTONE.

The vegetable matter which is diffused through the limestone of Burdiehouse forms a peculiar feature of its character. In some parts of the bed, more particularly in its higher seams, carbonized matter appears in such an extraordinary quantity, as to impart to the limestone a dark bituminous appearance. In other sites, however, where such matter is less abundant, the rock retains its prevailing bluish-grey or brown colour.

Amidst this carbonaceous diffusion, which must have resulted from vegetable matter in a decayed and pulverulent form, a profusion of fossil plants, analogous to those of tropical climates, appears encased in the rock in the most perfect state of preservation imaginable. It is, however, much to be doubted if this vast assemblage admit of much variety among them, at least in proportion to the immense mass accumulated.

The plant which occurs in the greatest abundance is the fern to which the name of *Sphenopteris affinis* has been recently given. It is described by Messrs LINDLEY and HUTTON, as having a leaf which is bipinnate, the leaflets being deeply pinnatifid into five segments, each of which is divided into from three to five linear obtuse segments, which are broadest at the upper end, and which are marked with from one to three parallel veins. (*Fossil Flora of Great Britain*, plate 45.)

This beautiful and delicate fern derives its chief interest from prevailing in the deepest seated beds belonging to the carboniferous group of the south of Scotland. In tracing the succession of strata superimposed upon the transition schist of Cove in Berwickshire, the first plant, which, in developing itself, breaks the continuity of a long suite of previously formed sandstones, little varying, and unfossiliferous in their geological character, is the *Sphenopteris affinis*. I found it here enshrined in a bed of bitu-

minous shale, where it appeared as a sort of harbinger to the rich primeval flora, which was doomed to follow. And in other sites, namely in Linlithgowshire and Ayrshire, the *Sphenopteris affinis* equally shewed itself as one of the first created plants of the carboniferous epoch.

Much rarer ferns, which in the limestone of Burdiehouse appear associated with this very ancient plant of the coal-fields of Scotland, are the *Sphenopteris bifida*, the *Sphenopteris linearis*, and some few others.

The *Sphenopteris bifida* exhibits a greater delicacy in the divisions of its pinnulæ than a fern which it greatly resembles from a different locality, the *Sphenopteris dissecta* of M. ADOLPHE BRONGNIART, to which the French botanist has assigned the highest antiquity among the carboniferous group of rocks. Yet there is still so much affinity between the two, that they might be readily confounded one with another. The fern of Burdiehouse, however, may be referred to a bipinnated plant which Messrs LINDLEY and HUTTON have distinguished by the name of *Sphenopteris bifida*. (See Fossil Flora, plate 53.) It is placed by these authors in the vicinity of *Sphenopteris myriophylla*, from which it is known by its leaves not having more than three or four primary divisions, and these not radiating from a common centre, and repeatedly dichotomous, but arising from a flexuose axis, and simply bifid. The difference between the *Sphenopteris bifida* and that of *dissecta*, as Professor LINDLEY has obligingly remarked to me, is, that the *Sphenopteris bifida* is a smaller plant with much more slender divisions, and with the principal pinnæ longer and more repeatedly divided.

The third *Sphenopteris* resembles one which has been hitherto only found at Oldham in Lancashire, having been procured by myself from a deep-seated bed belonging to the great coal-field of Lancashire. A specimen was many years ago placed in the hands of M. ADOLPHE BRONGNIART, who, in describing it under the name of the *Sphenopteris linearis*, has thus defined it: "*S. foliis*

bipinnatis, pinnis ascendentibus, rapidè decrescentibus, pinnulis obliquis, tri-quadrilobis, lobis bi-trifidis, laciniis truncatis approximatis brevibus multinerviis, nervulis dichotomis."—*Histoire des Vegetaux Fossiles*, tom. i. p. 175.

But this list of ferns might be much increased.

While by the luxuriance of their growth and their consequent numbers, these small ferns appear to have constituted one of the great divisions of the fossil flora of Burdiehouse, another set of plants not less numerous, comprise the doubtful tribe named Lycopodiaceæ, which, by their vegetation and mode of increase, approach in character to the comparatively minute vegetables of recent growth, the Lycopodia, or even to the order of Cycadeæ of far larger dimensions, while by their reproductive organs they have some little affinity to the Coniferæ. In the present instance, those peculiar structures of vegetable organization, which, separately considered, would seem of different character, but which have been conjointly regarded as the dissevered organs of the anomalous Lycopodiaceæ, appear in this limestone under circumstances of as great mystery as in other places, except that the cone, or one of the supposed organs of fructification, is too frequently in approximation, if not in absolute contact with a dichotomous stem, to sanction any other inference than that each is attributable to one and the same plant. Specimens of the *Cardiocarpon*, or of that species of lenticular and cordiform, or reniform, fruit, equally assigned by M. ADOLPHE BRONGNIART to Lycopodiaceæ, have not to my knowledge been hitherto found in the limestone.

With respect to such of the stems of Lycopodiaceæ as have been discovered, some of them may be referred to *Lepidodendron selaginoides*, (*Plates 12 and 113 of LINDLEY and HUTTON's British Flora*), to *L. obovatum*, (*plate 19 bis of the same work*), and to *L. Steinbergii* (*plate 112*). Among the leaves which have been attributed, though doubted by others, to Lycopodiaceæ, are those of *Lepidophyllum intermedium*, (see *Plate 43 of LINDLEY and*

HUTTON). The circumstances under which these vegetable relics are found, appear to be the same which had been previously remarked in another and very distant locality. At Burdiehouse, the *Lepidophyllum intermedium* is found lying along with *Cyperites bicarinata*. But whether this coincidence ought to stimulate to any fresh inquiry regarding the true character of each, I would not offer any opinion whatever, as it is but too possible that the association might have been purely accidental. At least, "it is curious," as Professor LINDLEY has remarked to me, "that these two fossils, which have no sort of relation to each other, should have occurred in association with each other, both in the Lee-botwood coal-pit and at Burdiehouse." (*Compare plate 43 of L. & H.'s Fossil Flora with Fig. 5 of Plate VI, given in this memoir.*)

Regarding the cylindrical and imbricated cones supposed to be naturally connected with the *Lepidodendron*, (a notion to which much countenance is given by the character of the remains discovered at Burdiehouse), two kinds may be identified, viz. the *Lepidostrobus variabilis*, (LINDLEY and HUTTON), *Pl.* 10 and 11), and the *L. ornatus* (*ibid.* *Pl.* 26).

No *cardiocarpon* which can be safely attributed to *Lycopodiaceæ* has yet, to my knowledge, turned up. I have only observed the *Cardiocarpon acutum* of Messrs LINDLEY and HUTTON (See *Foss. Flora*, *pl.* 76), which is supposed by them to belong to other plants.

These very general remarks must, on the present occasion, be deemed sufficient.

It is thus shewn, that the smaller ferns, referable to *Sphenopteris*, together with the disjointed organs of *Lycopodiaceæ*, constitute the great majority of vegetable remains entombed in the limestone of Burdiehouse. Along with these are found, but comparatively in less number or quantity, relics of the *Stigmaria ficoides*, and of the less common species belonging to *Sigillaria*, *Equisetum*, *Calamites*, and *Cyclopteris*. But as attention is

now directed to the daily disclosures of the quarry, we may expect that, in the course of time, a list of the various genera and species of plants discovered in this interesting locality will be perfected.

NOTES TO SECTION III.

Fossil Botany is a subject of inquiry so beset with difficulties, as to demand an almost exclusive attention to it by the naturalist, if he would pursue it with success. For this reason, I should be unwilling to commit myself by any attempts to treat of the Fossil Flora of Burdiehouse more in detail; nor can such attempts be reasonably expected in a memoir so limited as this must necessarily be. Specimens of the more important plants, among which are some new ones already discovered, have been transmitted, not only from the collection made by the Royal Society of Edinburgh, but likewise from my own cabinet, to Messrs LINDLEY and HUTTON, to be described by them in their important work exclusively devoted to the Fossil Flora of Great Britain. Other specimens, though from my own private collection only, have been sent to M. Adolphe Brongniart, whose acquaintance I had many years ago the happiness of forming in Edinburgh, while he was prosecuting his important researches in Fossil Botany: and thus every opportunity has been afforded for having proper justice rendered to the plants of more peculiar interest which have already turned up; and, in reference to future disclosures from the quarry, other similar transmissions are meditated.

Hitherto, two plants only from the vegetable remains of Burdiehouse have been noticed, which were forwarded to Professor LINDLEY and Mr HUTTON, for their Fossil Flora, by their zealous and very intelligent correspondent Mr WITHAM. In the botanical description given of the *Sphenopteris bifida*, it is incidentally stated, (see vol. i. of the work, p. 147), that "the plant was communicated by Mr WITHAM, from the mountain limestone of the lime-quarries of Burdiehouse, near Edinburgh;" and, upon another occasion, a similar acknowledgment is rendered.

In the absence of any geological description whatever having been hitherto published of this limestone, the very name of Burdiehouse would have been unrecorded, if it had not been for this incidental circumstance.

I am given to understand, that it is intended to devote the whole of a very early number of the British Flora to an elucidation of the plants of Burdiehouse.

In reference to this anticipation, as well as to the chief object of this memoir, which is to illustrate the fresh-water character of the limestone of Burdiehouse, one plate only has been dedicated to its Fossil Flora.

Fig. 1. of Plate VI. is the *Sphenopteris bifida*.

Fig. 2. is a plant, unfortunately not in the most perfect state, which I am inclined to consider as an undescribed *Sphenopteris*. But, as I agree with Mr HUTTON of Newcastle, in the possibility that the specimen may be

ultimately referred to the *Sphenopteris bifida*, any farther notice of it will be suspended.

Fig. 3. is the *Sphenopteris linearis*.

Fig. 4. is the *Sphenopteris affinis*. In this sketch the *Rachis* is rather too slenderly drawn.

Fig. 5. is the *Lepidophyllum*, in connection with *Cyperitis bicarinata*.

Fig. 6. shews the *Lepidostrobus variabilis* enclosed in the same specimen with a fish of the genus of *Palæoniscus*, which will be described in the 7th section of the present memoir.

SECTION IV.—THE MICROSCOPIC ANIMALS CONTAINED IN THE LIMESTONE OF BURDIEHOUSE.

No conchifera, at least of any large size, have hitherto been discovered in the limestone of Burdiehouse.

From having witnessed the great abundance in which fresh water unios are contained within a thin band of limestone and shale, near Old Cumnock, in Ayrshire, and from having read in Mr URE's History of Rutherglen, that they had been found under similar circumstances near Glasgow, I had long anticipated their discovery in the fresh-water limestone of Burdiehouse. But, if not found in the bed itself, they at least exist in a superincumbent bed of argillaceous shale which encloses similar organic remains.

The animals actually found in the limestone of Burdiehouse merit a particular regard: For there are assuredly no phenomena connected with the deposit of Burdiehouse more remarkable than the Entomostraca with which it abounds.

These minute animals are severally microscopic, ranging from $\frac{1}{12}$ th to $\frac{1}{60}$ th part of an inch. Various kinds are found among them, all of which, with perhaps the exception of one genus, appear to have been perfectly undescribed. Nor is it the easiest of tasks to submit them to any kind of successful investigation. We see nothing more in these crustaceous animals than their outer and shelly case, while a mineralized state has obscured their internal organization. Accordingly, if we conceive that certain minute oval bodies resemble recent specimens of the *Cypris*

Faba, or any other of the microscopic animals which are the tenants of stagnant waters, the identity can only be inferred from some external form, not always unambiguous, as for instance, from a bivalve shell possessed in common with conchifera.

I shall endeavour to describe some few of the infinite entomostraca which are found in the limestone of Burdiehouse, all of which are powerfully magnified. The little points inserted below each, shew the natural size of the animal.

Perhaps no minute animal found in this limestone is obtained under circumstances of greater distinctness than the Cypris.

The Cypris, as is well known, is represented as having two antennæ, straight, simple, and like a pencil of hairs at the top. It has a single eye, and it has four claws. A bivalve shell, the only part preserved in a fossil state, encloses the body. The head is concealed.

In the present instance, the Cypris of Burdiehouse, which is enclosed in a bivalve of a striking egg-shell complexion and whiteness, differs from the Cypris *Faba* of geologists in the straightness of its hinge, by which the form of a bean (whence the name of *Cypris Faba*), becomes lost.

In the annexed wood-cut, the greatly magnified, as well as the natural microscopic form of the Cypris, meet with a representation: *a* and *c* represent the general form of the shell, while *b* is a separate and open valve.



This interesting cypris is so characteristic of the deposit of Burdiehouse, that an appellation expressive of its locality would perhaps form its most suitable distinction. The limestone, which is its matrix, occurs close to the village of Bourdeaux, whence, by corruption, Burdie. And hence the name assigned to the locality by the French retainers of Queen Mary is most applicable in the present instance; it suggests the designation of CYPRIS SCOTO-BURDIGALENSIS.

In the next place, if it be allowable from analogy, rather than

from any other circumstance, to infer that certain of the minute animals thus described are referable to the Cypris, the prosecution of this research cannot be more safely conducted than in still confining our attention to the recent family of the Cypridea, for the detection, if possible, of other forms belonging to animals presumed to be of common habits. Another form, for instance, rather approaches to that of the Daphnia than the Cypris. But if, instead of an external crust, we could arrive at the knowledge of an internal organization, it is not improbable that the entomostraca thus compared might prove to be different animals altogether.

It is for this reason that I would name the animal represented in the three different views of the annexed wood-cut, by the cautious name of Daphnoidia rather than Daphnia; indicative of an individual approaching to the recent Daphnia.

The shell of the Daphnia, like that of the Daphnoidia of Burdiehouse, is not described as exactly bivalve, but as *subuni-valve*, opening longitudinally on one side only of the encased animal. This character may, I think, be plainly detected in the instance of the fossil example. I shall not venture upon assigning to it a specific name, until I am better assured with regard to its proper generic character.

Other minute animals possess shells of extreme tenuity, too many of which appear in a crushed and broken state. In this form they exhibit a sort of spiral organization by no means unlike that of the Planorbis or Spirorbis, to which they were referred by an eminent conchologist, whose opinion regarding them I consulted. But, upon a renewed examination of certain of these remains, which, owing to an infiltration of calcareous matter, have had their forms tolerably well preserved, I am now inclined to place some doubt upon the judgment which had been passed upon their character.

The external form of one animal most resembles that of the

Nautilus, but we are totally precluded from identifying it with that class of Mollusca, as the internal constitution of its shell shews no septa whatever; but, on the contrary, approaches to that of the Planorbis. It may perhaps be considered as a new genus altogether,—referable to mollusca. The dimensions of this microscopic animal are two or three times those of the Cypris. Its natural size appears in the representation inserted below the magnified form.

The foregoing best defined forms which have come under my notice, may for the present suffice. A microcosm of entomostraca, and possibly of other classes of animals, invites the attention of the naturalist, among which many undescribed races remain to be detected.

Some of these minute beings have been thus proved to possess a structure in common with that of well known entomostraca, whose habitat is one of stagnant waters rendered turbid by decayed vegetables or roots. When these waters are dried up by the sun, they still linger within a humid basin, and remain there until rains fall anew.

This habitat agrees with every possible circumstance connected with the limestone of Burdiehouse,—with the memorial of some inland fresh-water lake or tank, within the waters of which a calcareous deposit was elaborated, or of some river flowing sluggishly through a tract overrun with Ferns, Lycopodiaceæ, and such aquatic vegetables, as must have flourished among primeval marshes.

The abundance in which these animals appear is the last extraordinary circumstance to be noticed.

Although the remains of these entomostraca occur in much greater quantity in some parts of the rock than in others, there is scarcely a detachable fragment which does not exhibit their presence; and when, during the process of quarrying, a plane of stratification belonging to any portion of the limestone bed has

been allowed to remain long exposed to the air, so that some little of its surface has become removed by weathering, the crustaceous or shelly coverings of these minute beings become better defined, and their numbers are more palpably brought to light. In fact, I possess specimens which are almost rendered oolitic by the crowded state of these little animals.

These examples, while they shew to what an extent this primeval lake or river had once teemed with animal life, equally prove the quietness with which its calcareous deposit was conducted, and, consequently, the stillness and stagnation of these marshy waters, in which vegetables, together with entomostraca, have found so extraordinary a diffusion, as well as so extraordinary a conservation of their outward form and character.

NOTES TO SECTION IV.

Mr URE, in his History of Rutherglen, who wrote forty years ago, has the merit of having first directed the attention of naturalists to the microscopic shells which he found at Lawrieston and Stuartfield; but he does not make us acquainted with the description of beds in which they occurred at these places. He adds, that he also found them in a limestone quarry, about fifteen miles west from Newcastle-upon-Tyne, near the spot where the Roman wall is intersected by Watling Street. One of the specimens, of which he gives a magnified representation, is evidently that of a Cypris. (See URE's *History of Rutherglen*, p. 311.)

SECTION V.—THE DISCOVERY OF OSSEOUS REMAINS IN THE QUARRY OF BURDIEHOUSE.

That various kinds of fish were enclosed in the limestone of Burdiehouse, was a fact of which I was apprised upon the first occasion of my visit to the quarry.

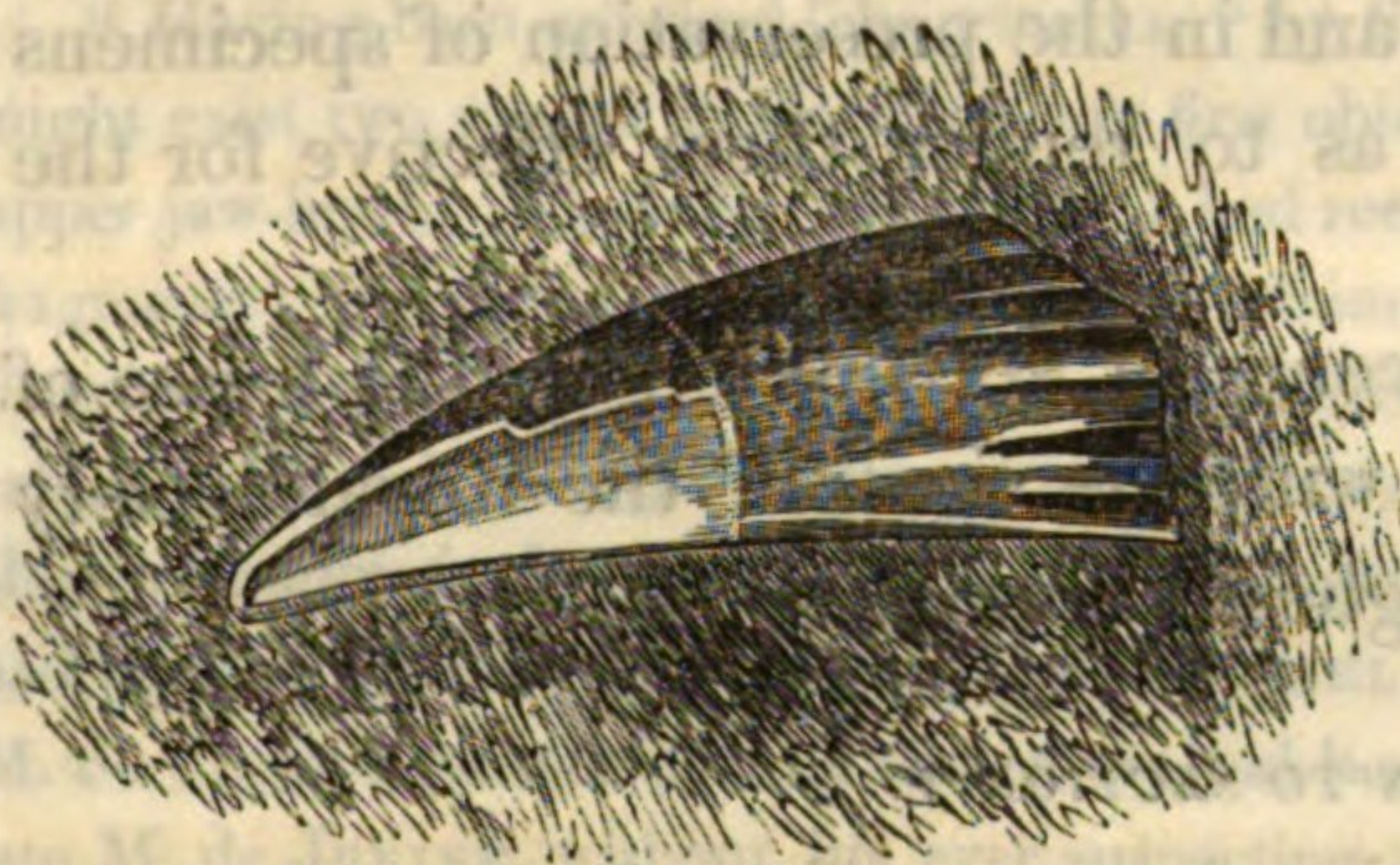
My earliest communication to the Royal Society of Edinburgh, relative to the limestone of Burdiehouse, was limited to the information, which I considered as an important one, that, in reference to its organic remains, it had no characters in common with the mountain-limestone of marine origin; but that, on the contrary, the immense abundance of plants which it contained,

along with entomostraca and fish allied to such as are found in coal-measures, rather justified our considering it as a fluviatile deposit.

The view which I had thus taken of the Burdiehouse limestone, was made known to the Royal Society on the 2d of December 1833.

A single day, however, had not elapsed subsequent to this communication having been read, when another discovery, perfectly unlooked for, ensued. I had charged the workmen employed at the quarry of Burdiehouse to carefully preserve for me any animal remains which might turn up; and, upon revisiting the place, in company with Mr WITHAM, one of the labourers brought me a fragment of limestone, enclosing a tooth, two inches and a quarter in length, which was in the most beautiful state of preservation that can well be imagined, possessing an enamel of a nut-brown colour, which shone with all the brilliancy of perfect freshness.

This tooth, which is represented in the annexed wood-cut, I



conceived, from its outward form and external structure, to belong to a large animal of the Saurian class. I also procured some other relics, apparently of the same monster; and was led to

remark, that the limestone contained coprolites, referable, from their size and from the undigested scales of small fish diffused through them, to some voracious sovereign of primeval waters.

After this discovery was made public, the workmen were encouraged to look after the relics which might turn up; and I gave them full credit for sincerity when they assured me, to a man, that, in the long course of their quarrying operations, no remains whatever, save those of plants, had ever been the object

of their visual organs. But having been now convinced that bones did actually exist in the limestone, and having been excited by the promise of a reward if they should find more such relics, I was presented with an excellent physiological example of the capability which such a stimulus had of increasing, to an almost miraculous degree, the vividness of optical perceptions. The men, to use their own words, now "saw with new eyes." Large scales, large bones, along with the remains of small fish, became palpable, and, as if by the force of a magician's spell, were revealed in a profusion most admirable to behold.

When the quarry had been thus introduced to public notice, a complete dispersion of its fossil treasures seemed inevitable. With the view of preventing a catastrophe so much to be dreaded, I invited the interference of that influence which the Royal Society of Edinburgh possessed as a body. The appeal was not made in vain. To their General Secretary, Mr ROBISON, the acknowledgment is due of having successfully rendered his invaluable aid in the prevention of a most injurious dispersion of the osseous relics of the quarry, and in the preservation of specimens in such an assembled form, as to render them effective for the requisitions of science.

The very liberal acquiescence of Mr TORRANCE, the lessee of the quarry of Burdiehouse, with the views of the Royal Society of Edinburgh, merits the highest encomium.

NOTES TO SECTION V.

The following explanation regarding the quarry will not, I trust, be found irrelevant. I owe it no less in justice to certain individuals, than to the Royal Society of Edinburgh.

Very soon after my discovery, the hopes which I had entertained of the extraordinary acquisitions which geology would derive from it, were soon threatened with frustration. A sort of scramble had ensued among scientific individuals (which it must be allowed was a very natural one), to obtain for themselves valuable specimens from the quarry of Burdiehouse: and thus, the great disastrous result which fossil zoology most dreads, namely, the dispersion of its relics, and the difficulty, if not impossibility, of reuniting them, seemed inevitable.

A scramble of this nature, in reference to such a fatal result, not a little resembles the every-day occurrence of workmen who, in the course of digging, have fallen upon some ancient urn which contains the cremated ashes of our Celtic or Teutonic progenitors. The pick-axe is supposed to have been resisted by "a pot of money;"—a tremendous scramble ensues; the urn is broken into a thousand pieces, and the antiquary resigns himself to despair.

Under these circumstances, I took the first occasion in my power to obviate a catastrophe which appeared so imminent.

In addition to recommendations which I drew up for the public journals, urging the patrons of the College Museum, or the Council of our leading scientific institution of Edinburgh, to exert a fostering care over the quarry, and to prevent the dispersion of its relics, I took an early occasion, at one of the meetings of the Royal Society, to make a personal appeal on the subject.

Upon this occasion, I stated, that the great French naturalist, to whom geology has been most indebted, laboured under no difficulty so great as in his endeavours to counteract the dispersion of osseous relics of comparatively little value in a separate state, but most important to science when collected together with a view to the appreciation of the whole in their united condition. This difficulty I illustrated by a few passages from the writings of CUVIER, which shewed the almost incredible labours to which he was obliged to resort, before he could reassemble certain dispersed fragments necessary for him to come to a satisfactory conclusion respecting the fossil saurian animal of Honfleur.

"Having been apprised," he remarks, "by these two lower jaw-bones, that there might exist two species at Honfleur, my first object was to regain the skull and the upper jaw-bone. The collection which I had received from Rouen afforded me some fragments; but the original owner had entertained the unfortunate notion of getting them cut and polished; and he had even distributed a part of them among other cabinets. It is by a series of almost incredible events, that I have collected and been able to reunite six fragments, which had belonged to the same cranium, of which two had been in the possession of the Abbé BACHELET, two had found their way into M. de DRÉE's museum, while two others had been sent to me from Geneva by the late M. de JURINE, without his ever suspecting their importance in this particular inquiry. By means of these six pieces, I succeeded in reconstructing a considerable portion of the cranium containing the occiput, the greatest part of the upper face, and sides, as far as the snout. It is by similar accidents that I have collected three fragments, which had belonged to one and the same snout, and of which I had only given two in my first edition. These two last were in the museum of the late Abbe BESSON; the third was in that of M. FAUJAS, to whom BESSON had given it, without perceiving that, along with the two others, it only formed one entire whole."

The force of this quotation I urged, in connection with the remark, that it would be chimerical for a single individual like myself, perfectly unsupported, to suppose

that he had either the means or the influence to counteract such a fatal dispersion ; but that the pecuniary means, and, above all, the command of influence possessed by a scientific body like that of the Royal Society of Edinburgh, might, with the greatest prospect of success, be exerted in so important an object.

The Council of the Royal Society, with a liberality of which I cannot speak in too high terms, immediately responded to the representation, and appointed their General Secretary, Mr ROBISON, with funds at his disposal, to superintend the task, aided by a small Committee.

The task could not have been entrusted to more able hands. Mr ROBISON immediately addressed himself to Mr TORRANCE of Meadowbank, the lessee of the quarry, requesting his co-operation with the views of the Royal Society of Edinburgh ; and, to the honour of the latter be it added, his assent was immediately obtained. While any dispersion of the relics discovered was strictly forbidden, the labourers were at the same time amply remunerated for all the specimens which they were enabled to collect.

These measures were very soon the means of obviating the dispersion of the osseous fragments of the quarry ; which object was still further promoted by a few of the gentlemen who were extensive geological collectors themselves abstaining from any attempt at purchases, and thus setting a laudable example of self-denial.

During the whole of the last winter and some part of the spring, not a week was allowed to intervene without the quarry being visited, either by Mr ROBISON or myself, always on alternate days ; and by this surveillance, aided by the injunctions of Mr TORRANCE, and the remonstrances of the worthy minister of the Parish, Mr PURDIE, a constant check was placed upon any clandestine disposal of the bones, and, perhaps, as few breaches of confidence occurred as might be expected from an assemblage of quarrymen, many of whom were burdened with large families.

Toward the accomplishment of another object, Mr ROBISON's labours were unassistedly directed. The osseous fragments discovered were firmly embedded in a hard limestone rock, and nice mechanical skill was requisite to detach them from their matrix ; which difficulty was again augmented by the very conchoidal fracture assumed by the limestone after a blow of the hammer, and the consequent difficulty in regulating the extent and direction of the cleavage, or of the chippings. Now, in order to overcome these obstacles, Mr ROBISON laboured with success, and invented a small dressing hammer, which effectually brought under control the destructive fractures into which the limestone was liable to split. This hammer will be soon considered as indispensable to the manual operations of the geologist.

The result of these exertions may be readily anticipated. The enlisting of a gentleman of such well known mechanical science as Mr ROBISON, in the task of detaching these osseous relics from their stubborn matrix, and of bringing them to light in a state of integrity, was a result truly favourable to the best interests of Geology. Very minute specimens, even those which embraced the almost microscopic fry of the immense questionable animals of Burdiehouse, were developed with a distinctness,

which has not a little contributed to solve some important questions which the osseous relics of the quarry have suggested.

While Mr ROBISON was thus rendering the most valuable assistance in the common object which we had in view, this co-operation was the means of affording me the more leisure to satisfy myself regarding other questions of geological interest suggested by these researches.

SECTION VI.—THE GENERA OF FOSSIL FISH DISCOVERED AT BURDIEHOUSE.

The fish discovered at Burdiehouse will be described after the system of M. AGASSIZ, Professor of Natural History at Neuchâtel, whose "*Recherches sur les Poissons Fossiles*," is already familiar to most geologists. They will also be noticed in connection with the judgment passed upon them from personal inspection by this eminent naturalist; and, in availing myself of the kind assistance which he has thus rendered me, I would confess to an obligation for which I am truly grateful.

M. AGASSIZ's system, as is well known to those who may have but glanced at his work, while it carefully includes the distinctions which prevail in older recognised systems, gives a characteristic pre-eminence to that portion of the structure of the fish, which with geologists ought to claim a leading consideration. The skin of the fish connects the animal with the medium in which he lives. It is the essential character of the skin to form a sort of external skeleton, which protects its surface. Its epidermis may be considered, in the most general point of view, as a membranous layer of horny substance, which covers the whole surface of the animal, which isolates it from the external world, which shelters the more delicate part of its organization, and which, as a bad conductor of heat, preserves to it that degree of internal temperature which is essential to its vitality. While this covering is composed of a number of layers, or folia, superimposed upon and strongly adhering to each other, it is at the same time insensible, and is reproduced with ease.—*Recherches sur les Poissons Fossiles*, tom. i. p. 26, &c.

In reference to this most important portion of the structure of the animal, the great orders of M. AGASSIZ's system are founded.

The remains of such fish discovered at Burdiehouse as I intend to notice in the present memoir, are referable to two of these orders.

The first of these orders includes Placoidian fish. They are distinguished by the irregularity manifested in the solid parts of their integuments, which consist of materials of enamel often considerable, or sometimes reduced to little points; as, for instance, the tubercles of rays, or the different chagrins of squali, &c.

To this order M. AGASSIZ has referred the fish to which certain bony rays of gigantic dimensions found at Burdiehouse belong. The animal is supposed to have approached the Cestracion of modern times; which fish is the type of the family of Cestraciontes. He conceives that the remains in question may be referred to a new genus, to which he has given the name of *GYRACANTHUS FORMOSUS*.

Other relics are referred to fish of a second or Ganoidian order, distinguished by the angular, rhomboidal or polygonal scales, which they possess in common; these scales being at the same time formed of bony plates, and covered over with enamel. This order includes various families, but, in reference to the fossil remains of Burdiehouse, two only of them will have to be considered.

To the family of Lepidoids (*Agass.*), which are characterised by teeth after the form of a brush disposed in several rows, or in one single row of small obtuse teeth, three genera discovered at Burdiehouse have been assigned, viz. the *PALÆONISCUS*, the *AMBLYPTERUS*, and a new genus, to which M. AGASSIZ has given the name of *EURYNOTUS*.

To the family of Sauroids, which are distinguished by conical and pointed teeth, alternating with small teeth *en brosse*, by flat scales, rhomboidal and parallel to the body, which is entirely co-

vered by them, and by an osseous skeleton, M. AGASSIZ has attributed the remains of two fish which have been found. One of these belongs to his genus *Pygopterus*, and another to an undescribed and extraordinary genus, the *Megalichthys*.

This list could no doubt be extended. I am therefore called upon to remark, that, as the entire suite of specimens hitherto collected at Burdiehouse has been submitted to the investigation of M. AGASSIZ, to be illustrated by him in his "*Recherches sur les Poissons Fossiles*," it would only burden the volumes of the Royal Society's Transactions, to enter into a description of all the fish discovered in the quarry. For this reason, I have proposed to confine myself to such individuals only, as might serve for illustrations of the general character of the limestone, or might involve geological questions of importance.

NOTES TO SECTION VI.

Soon after my discovery of the fossil treasures of the Burdiehouse limestone, I was anxious to obtain M. AGASSIZ's judgment upon them; and, accordingly, very early during the last spring, I wrote to him, with drawings of three of the best marked specimens which had then been found. Since that period many others have been added to the collection of the Burdiehouse specimens, and when, upon the occasion of the British Association of Science meeting at Edinburgh, I had the satisfaction of cultivating a personal acquaintance with M. AGASSIZ, he promised to favour me with his opinion regarding all such specimens as I might submit to his consideration.

That I should have consulted M. AGASSIZ in preference to any other naturalist, however eminent he might have rendered himself in other departments of zoology (and I would add that there are zoologists in Scotland whose memoirs form very valuable portions of the Royal Society's Transactions), cannot create the least degree of surprise among such as are aware of the most imperfect state of our knowledge in fossil ichthyology, and of the great light which is dawning upon this obscure branch connected with geology, by the transcendent researches which are going on under the auspices of the Swiss naturalist.

To those who may happen to be unacquainted with M. AGASSIZ or his writings, it is sufficient for me to explain, that he appears before us under two great recommendations.

In the first place, he has taken up the elucidation of a branch of natural history, conceded to him as untrod ground by no less an individual than CUVIER himself,—himself a giant in the field of palæontology. This fact is rendered evident by the

acknowledgments which M. AGASSIZ pays to the French naturalist for having committed to his possession all the materials which the Baron had himself collected with a view to similar researches, for which his important occupations in another department, namely, in the extinct land, and amphibious animals of a past state of our globe, had afforded him too little leisure.

A second recommendation of M. AGASSIZ is, that he comes before us not only in the character of a zoologist, but as one who has studied the character of fish in reference to their geological connections; who has endeavoured to trace in this class of animals the changes of organization which have happened in correspondence with the various revolutions which the earth has undergone. "Fish," as he observes, "being more than all other animals most intimately connected with the incidents of the water, and their organization being besides very high up, they are better calculated than any other class to give us clear ideas regarding the changes which have been going on in such vast seas as have formerly covered over the earth. We shall be enabled to determine if a fish has lived in rivers, in lakes, or in ponds, in the high sea, or upon its shores;—if it was an inhabitant of the surface of the water or of its great depths;—which indications, more or less valuable, will aid us in determining corresponding circumstances with regard to the formation of rocks."

If I had space allotted me in this memoir, I could point out many instances of the tact which M. AGASSIZ evinced while in Edinburgh, illustrative of the importance of fossil ichthyology, in the assistance which it yields in determining the relative age of rocks, and which would show, at the same time, how inexcusable I should have been if I had not availed myself of a judgment of such value as that which he has evinced.

SECTION VII.—THE FOSSIL FISH REFERABLE TO THE LEPIDOID FAMILY.

For motives of convenience, I shall not describe the fish which I mean to notice in the exact order of classification already explained.

As I have stated, the Lepidoid family is included in the Ganoid order of fish.

To this family the genera of Palæoniscus, Eurynotus, and Amblypterus are referred, of which one species or more of each have been discovered in the quarry of Burdiehouse.

The fish which the limestone entombs in far the greater number is an individual which I had little difficulty in referring to the genus of Palæoniscus. (*The first specimens discovered of this fish were sketched in Plate VII., figs. 1. and 3. But more perfect ones having been subsequently obtained, they are introduced*

in Plate VI., Figs. 6. and 7., where one of them appears in a specimen which encloses also the vegetable relic named the *Lepidostrobus variabilis*.)

A doubt at first arose whether the fish formed a new species, and the more particularly as it approached in character to the *Palæoniscus angustus* of Autun. (See "*Recherches sur les Poissons Fossiles*," tom. ii. page 57.)

M. AGASSIZ has, however, referred the specimen to a perfectly undescribed species; and, in pointing out the small pectoral and the small ventral fins which it possesses, as well as the anterior edge of the dorsal fin being opposite, or nearly so, to the ventrals, he adds, "what principally characterises it, is its elongated form and the thinness of its body, by which it comes nearest to the *Palæoniscus angustus* of Autun; but, at the same time, it differs from all other species belonging to the genus, in the much more considerable length of the anterior rays of its dorsal and anal fins, and in the considerable size of its tail."

With the name which ought to be given to this new species, M. AGASSIZ has declined to interfere. He states, that in a letter which I wrote to him, directed to Neuchatel, accompanied with a drawing of the fish, I had, in this instance, successfully attributed it to the genus of *Palæoniscus*; on which account he would wish its specific name to rest with myself. An opportunity has thus been afforded me, of which I hasten to avail myself, of paying the public acknowledgment which I owe for the unwearied pains taken by Mr ROBISON, General Secretary of the Royal Society of Edinburgh, not only in preventing the dispersion of osseous relics so important to geology, but in otherwise affording me the greatest assistance in the prosecution of these researches. As a tribute, therefore, of the gratitude which I feel for such services, I would beg to name a new species of fish, which, from its great abundance, may be almost regarded as characteristic of the limestone of Burdiehouse, the *PALÆONISCUS ROBISONI*.—
See Plate VI., Fig. 7.

A second fish is considered by M. AGASSIZ as constituting a new genus of the same Lepidoid family, referable to his *Lepidoides hétérocérques*. (See the Plates of the first volume of *Recherches sur les Ossements Fossiles*.) This genus is considered as coming near to that of the *Palæoniscus* and *Platysomus*. M. AGASSIZ writes to me regarding the fish as follows: "I intend to call it EURYNOTUS. What characterises it the best is the great size of the dorsal fin which occupies the whole back, as in the *Platysomus*, the anterior rays of which are very much elongated. Fig. 4. of Plate VII. does not give a complete idea of it, the anterior edge of the dorsal fin being much more elongated. M. JAMESON has placed in my hands some, almost perfect, specimens of the fish, which, at first, I did not recognise, so remarkable was their aspect. The anal fin is narrow, but its rays are elongated. The general form of the body is rather that of the *Amblypterus* than of the *Palæoniscus*, but its double fins, the pectorals and the ventrals, have fewer rays, and these rays are longer. The scales (which, like other parts of the fish, are not very well preserved in the specimen of the Royal Society) are not so long as they are high, and their posterior edge is crenulated and indented; for which reason, I have called this species, hitherto the only one known of the genus, EURYNOTUS CRENATUS."

A third fish, referable to the Lepidoid family, is a species of *Amblypterus* (*Agassiz*), of which I possess no drawing nor description. It will doubtless be noticed in the "*Recherches sur les Poissons Fossiles*."

SECTION VIII.—THE SAUROID CHARACTER OF CERTAIN OSSEOUS REMAINS ENCLOSED IN THE LIMESTONE.

A circumstance of no little interest, connected with the organic remains which had been disclosed during the progress of quarrying, was the question which they involved regarding their conceived saurian character.

In the first place, a large tooth was obtained, having no little

resemblance to those of the Gavial of the Ganges. (See Plate VIII. fig. 1.) Nor did the internal structure of such teeth as were discovered forbid the supposition. This is shewn in the annexed figure, which represents the section of a tooth, which had been

found broken longitudinally:—*a* represents a lower and outer portion of the tooth, while *b* is its reverse side, in which an internal cavity is observable, at present filled up with earthy substance, not unlike the cavity observable in the teeth of large reptiles, which is supplied with a replacing tooth.



ble in the teeth of large reptiles, which is supplied with a replacing tooth.

The larger longitudinal fragment of the same tooth is represented by *c*, in which the counterpart of the same internal cavity is discernible.

It is true that this internal structure was not a decisive mark of the animal having been a reptile, yet, when the immense size of some of the teeth subsequently discovered was also taken into consideration (see Plate IX.), one of which was $3\frac{3}{4}$ inches in length, and when no extinct animal coeval with or earlier than the new red sandstone formation had been hitherto recorded as possessing such immense teeth, saurian reptiles alone excepted, the reference of the teeth to such animals was, at least, the most ready supposition, and justifiable.

In the second place, various scales were collected. These were of two kinds.

The first of these comprised the remarkable structures which are represented in Plate VIII. fig. 2. It is not the first time that these scales have been discovered in coal-fields. They have even been figured as fungi belonging to the vegetable world. In the present instance, it may be supposed that these substances had, in the limestone, met with a better state of preservation, as it was impossible not to be struck with their internal cancellated structure, which forbid any supposition but that they were osse-

ous. Owing to this structure, and to their rounded form, it was conceived that they were the epiphyses of vertebræ; but other specimens having been obtained in which an external lamellar structure might be also remarked, this notion was discounted, and the relics in question were adjudged to be large scales. But, with regard to the animal to which these scales might be referred, no supposition was hazarded. Indeed, some little mystery regarding them may possibly subsist at the present moment. (*Other representations of these scales appear in Plate X. and Fig. 2 and 3.*)

A second description of scales possessed great thickness. They were adorned with a brilliant enamel of a nut-brown colour. They were of an angular, rhomboidal, or polygonal form, and most of them exhibited small pits or dots upon their surface, (*see Plate XI. Fig. 4 to 7*). Now, it is certain that any opinion which could be formed from these scales was at the best equivocal. Although I at first advocated their exclusively saurian character, yet, when I saw a large specimen of the *Lepisosteus*, named by M. AGASSIZ the *Lepidosteus*, which is preserved in the British Museum, I immediately considered the possibility that the scales might belong to some animal of the finny tribe, which suspicion was stated in the memoir that I read at a sectional meeting of the British Association. At the same time, a comparison made with various crocodiles, collected from different countries, not only shewed me scales of the self same form and thickness; but even the very pits or dots by which I at first conceived the scales of the Burdiehouse animal were to be distinguished. So far, then, the saurian evidence was scarcely decisive.

In the third place, a discovery was made of bony rays of extraordinary dimensions and beautifully configured. (*See Plate XI. fig. 1, A and B.*) Others also, of a different form, and of less size, were found. Regarding these relics, no question at all could arise. They evidently belonged to fish, and could not by any possibility be confounded with the remains of reptiles.

In the fourth place, very large disjointed bones, generally cranial, were disclosed. These were in such a broken and unconnected state as to throw no light whatever upon the saurian question. Some of them appeared fish-like; and, as it was certain, from the discovery of large *Ichthyodorulites*, that immense fish must have existed, a reference was easily made. But, on the other hand, certain bones were strikingly reptilian; and, accordingly, it was judged possible that the latter might have belonged to the animal to which the teeth had been referred.

Such was the character of the osseous relics which had been discovered. No important bones were in a state of connection, or integrity, with the exception of a jaw so very minute as to be comparatively microscopic, (*see Plate IX. fig. 1.*) Of this relic, however, an important use was made, as will soon be shewn.

From the foregoing statement it would appear, that, while the scales, and many other bones, yielded rather ambiguous evidence in determining an exclusively saurian question, it was the character of the teeth which afforded the greatest ground of presumption, that saurian reptiles had actually existed during the carboniferous epoch.

But, in order to arrive at the truth, the greatest desideratum was the discovery of some part of the head in which the jaws and teeth would prove to be in a state of connection. It is certain that two or three of such relics had been actually found, the inspection of which was never conceded to myself. M. AGASSIZ had the opportunity of a momentary glance at one of these remains, when he instantly conceived that it belonged rather to a sauroid fish than to a reptile. This suspicion having been communicated to me, I instantly recollected, that the portion of a very minute jaw, evidently belonging to one of the fry of the questionable animal, was in the possession of the Royal Society of Edinburgh; and, upon placing it under a strong magnifying

glass, M. AGASSIZ informed me that the suspicion which he had entertained was still farther confirmed.

The conclusion eventually drawn from this examination was, that the large teeth, the scales, and many of the bones, did not belong to a saurian reptile, but to an immense sauroid fish.

NOTES TO SECTION VIII.

It had been long known among the workmen of the limestone quarry of Burdiehouse how anxious I had been for the discovery of any bones to which the teeth might be found to actually adhere; which anxiety arose solely from the wish that some additional light might be thrown upon the saurian question. Now, from some cause or other (which I will not seek to explain), relics of such importance as these never came into the possession of the Royal Society, although a price would have been advanced, even on my own account, should the Royal Society have refused to purchase them, fully equal to the sum any other individuals would have paid. Such a value, indeed, did I at one time place upon the discovery of teeth thus found attached, that for such a prize I would have been content that they should have been rated at the highest market price which our best dentists actually receive for teeth belonging to the *Homo sapiens* of Linnæus.

I had flattered myself that the line of conduct chalked out by myself during this investigation had been sufficiently appreciated. As I had publicly expressed my wish that some individual who had made zoology more a particular object of his study than myself, would undertake the business of describing the osseous remains discovered at Burdiehouse, and, as the specimens in the possession of the Royal Society of Edinburgh were open for consultation to every member of it equally with myself, and, indeed, to every scientific individual capable of forming a judgment upon an intricate question of comparative anatomy, I thus conceived that the possibility of any feeling of rivalry or jealousy being excited, was entirely out of the question.

It was not, however, at Burdiehouse alone, but in other localities near Edinburgh, that sauroid relics had been discovered, of no less importance towards the elucidation of truth. They constituted private property; and, of course, I had no right whatever to make any complaint that I was not permitted to avail myself of the information which they were calculated to impart. I am only entitled to express some little regret that no account of them had ever been published; otherwise, I might have been enabled much sooner to have reconsidered the opinion which I had expressed on the saurian question, and to have acknowledged my obligation for the correction of any error into which I might have fallen;—an acknowledgment which I have not hesitated to pay to M. AGASSIZ.

SECTION IX.—THE FISH OF RECENT TIMES CALCULATED TO EXPLAIN THE SAUROID CHARACTER OF THE OSSEOUS REMAINS DISCOVERED AT BURDIEHOUSE.

The conclusion arrived at by M. AGASSIZ could not but be regarded, as portending a splendid accession to our knowledge concerning the immense animals which lived in so early an epoch as that from which our coal-fields date their origin. The monsters which roamed among the more ancient waters of our planet, did not possess for purposes of locomotion, paddles or feet like those of the reptiles of later epochs ;—they were vested with fins, yet still exhibited along with the attributes of fish, a sauroid form of teeth, and a sauroid structure of the larger bones, in connection with the splendid scales of the crocodile, or gavial.

From these considerations a natural question arose,—Does any animal yet exist upon the surface of the globe, with which a monster of so mixed a character can be compared? A reply has been given in the affirmative.

Among the countless numbers of animated races long since extinct, there would still appear to be some approximating tribes, which linger on the present surface of the globe even during its very altered state. These might have been called into life under local or partial circumstances of subsistence, or habitat, alike common to some condition of a primeval state of our planet. But such concurrent circumstances, whatever they may be, we have not always the means of ascertaining.

It is sufficient to state, that, in reference to fish which possess important characteristics in common with those of extinct tribes, M. AGASSIZ, for purposes of comparison and analogy, has made a very diligent quest, as may be shewn by some striking illustrations which appear among his Ichthyological researches.

This naturalist, in establishing among his ganoid order of fish a sauroid family, had referred, as a type of it, to a recent sauroid fish, the principal species of which dwell among the lakes

and rivers of the warm regions of America. To this animal the name of *Lepisosteus*, or, according to M. AGASSIZ's altered nomenclature, *Lepidosteus* has been given,—a term significant of the hard, bony, and crocodilian character of its scales.

With this sauroid, yet finny inhabitant of the waters, M. AGASSIZ had already, as far as related to certain comparatively small sauroid fish enclosed in the carboniferous group of rocks, found much analogy. He had, however, still to learn, that sauroid fish of even gigantic dimensions were referable to the self same geological epoch. The knowledge of this important fact he first acquired at Burdiehouse.



The *Lepidosteus*, of which the foregoing is a representation, admits of three species, the *Lepidosteus spatula*, the *L. Gavial*, and the *L. Robolo*.

The *Lepidosteus Gavial* is so named from its actual resemblance to the crocodilian animal of the Ganges. "This fish," observes a naturalist, "has the greatest relations of external likeness with the saurian reptile, whence it has derived its name. These traits of resemblance are instantly recalled to the mind of the observer by the form of the head of the animal;—by the very great elongation of its jaws, by their little breadth, and by the furrow longitudinally hollowed out on each side of the upper jaw;—by the irregular osseous pieces, carved, radiated, and strongly articulated with each other, which envelope its head, or which compose its opercules;—by the quantity, the form, and the inequality of the teeth:—by the position of the orifices of the nostrils at the end of the snout;—by the situation of the eyes, which are placed very near the angle of the mouth;—by osseous scales which, being distributed over the whole of

the body, form an impenetrable cuirass against the teeth of other inhabitants of the water, and even against the ball of a musket, which makes no impression."—See the article *Lepisosteus* (by M. CLOQUET) in the *Dictionnaire des Sciences Naturelles*.

But I have now to communicate a most important addition to our knowledge relative to this sauroid fish, by which it is even still more closely approximated to animals of a reptilian character.

The cellular structure of the swimming bladder of the *Lepidosteus* had been long since remarked as curious, but it has been left to M. AGASSIZ to discover the use of this internal structure, and, along with it, that of the swimming bladder itself,—as this organ is usually named. Having been recently, by the British Museum, allowed the permission of dissecting a specimen of the *Lepidosteus*, preserved in spirits of wine, he has been so very kind as to favour me with the result of this most important anatomical investigation.

"You know," he observes, "that the nature of the swimming bladder of the fish is still an object of controversy among anatomists; some considering it as a particular organ peculiar to the class of fish, while others (the natural philosophers) suppose that it is analogous to the lungs. In examining this organ, as it is met with in the *Lepidosteus*, I have not only been enabled to demonstrate that it is a real lung, but I have also found a great approach in its structure to that of the lungs of reptiles. The lung (the swimming bladder) of the *Lepidosteus*, is not only cellular, as we find it to be in salamanders, and in the reptiles improperly named doubtful reptiles, but it also possesses a trachea (*trachée artère*), which is extended the whole length of its anterior surface, and which opens at the bottom of the mouth by a glottis surrounded by ligaments which close and shut it;—this apparatus being even more complicated than we find it to be in many reptiles.

“ The heart also has not the appearance of the heart of an ordinary fish. It is destitute of that inflation, so characteristic of fish, called *Bulbus-aorticus*, and has rather the aspect of the heart of a reptile.”

Such is the important information transmitted me by M. AGASSIZ relative to the *Lepidosteus*.

That the animal should have been found to possess lungs is a circumstance which may be availed of in certain geological speculations, and upon which some few remarks will be made hereafter. In the mean time I may observe, that, if the presence of lungs in their very complicated structure deserve to be considered as a reptilian character, which it is usually supposed to be, the *Lepidosteus*, instead of being regarded as a sauroid fish, rather deserves the appellation of a finny reptile.

But without insisting upon the propriety of the latter term, which, on account of other points of anatomical difference, particularly the form of the jaw, would be disputed, it may be, lastly, remarked, that the teeth, the scales, and various large fragments of bones which have been discovered at Burdiehouse, will be referred to an animal bearing the greatest affinity to the *Lepidosteus*, although far larger.

NOTES TO SECTION IX.

M. AGASSIZ, in his “ *Recherches sur les Poissons Fossiles*,” has given a drawing of the *Lepidosteus*, of which the wood-cut of this Memoir is a reduction. But in the present incipient state of his work, a full description of the animal has not yet appeared.

Soon after my Memoir had been read to the Royal Society of Edinburgh, in which I had supposed that a saurian animal was indicated by the teeth and scales which had been discovered at Burdiehouse, I obtained a glance only at the first number of M. AGASSIZ's work, in which the *Lepidosteus* was figured ;—(for my own subscription copy had been slow in arriving.) I remember having been struck with the animal's crocodilian appearance, which was the only impression I then felt, as I had not been able to subdue the conviction in my own mind, that the monster which possessed teeth like those which were found at Burdiehouse, must have been as completely a saurian reptile as the Gavial of the Ganges.

The impression produced upon my mind by the drawing was but faintly retained, until I visited the British Museum in London. Upon this occasion, an imperfect specimen of a large fish, with splendid scales, and form of head remarkably gavial-like, immediately arrested my attention. After having taken several notes of the external character of the animal, I added in my memorandum-book, "*This fish I must know.*" In fact, my suspicion was so excited regarding the validity of my exclusively saurian hypothesis, that after having been politely favoured by Mr GRAY of the British Museum, with a closer inspection than the highly suspended specimen of the *Lepidosteus* would permit, of smaller examples of the animal, I came to the conclusion that some of the large scales of Burdiehouse might have belonged to a fish,—an opinion which I afterwards supported. And, most probably, I should have dismissed every notion whatever which I had entertained in favour of an exclusively saurian theory, if it had not been for the remarkable character of the fossil teeth, which, after a consultation of the best works on comparative anatomy, I could not reconcile with the attributes of a fish.

It would be an easy matter for me to shew that I had not been solitary in my judgment, as it was the same which had been expressed by some of the first naturalists in London and Paris, to whom the teeth in question had been submitted. Even M. AGASSIZ himself, when I accompanied him to the collection of Burdiehouse specimens in the possession of the Royal Society of Edinburgh, with the view that he might select any of them for drawing which might enrich his great work, was so far inclined to countenance my opinion, that he rejected the teeth and many of the large bones collected, as not being objects of his department, considering, like myself, that they had belonged to a reptile.

It has been explained, however, that a single day had not passed over, before M. AGASSIZ obtained the momentary sight of a jaw of the animal; (for, as I have stated, more than two jaws at the least had been found, which I had never myself the opportunity afforded me to inspect); he then revoked his opinion, and pronounced the animal to be a sauroid fish, rather than an exclusively saurian reptile. Upon this occasion he begged me to accompany him to the College Museum, (my first visit there for many years), where he pointed out to me a very small specimen of the same *Lepidosteus* which had so commanded my attention in London, to which he now recommended me to direct my particular views of comparison.

SECTION X.—THE SAUROID REMAINS OF BURDIEHOUSE REFERRED TO A NEW GENUS OF SAUROID FISH, THE MEGALICHTHYS.

When M. AGASSIZ visited Edinburgh, he found the bones of the large sauroid fish of Burdiehouse in so broken a state, among which were fragments of the bones of other large and unknown animals, that they almost defied any attempt of successful con-

nection. In fact this labour is only in progress. The Royal Society of Edinburgh have transmitted to M. AGASSIZ as many of the specimens from the collection as he wished to examine, in order to be illustrated in his work; and it is to be hoped that more important relics will still turn up during the process of quarrying. The details, therefore, of which this memoir must necessarily be deficient, will no doubt be in the course of time supplied.

From another source, however, M. AGASSIZ has obtained most important information relative to the sauroid fish of Burdiehouse. After leaving Edinburgh in company with Dr BUCKLAND, these gentlemen visited many of the public museums of Great Britain, among which was that of Leeds, where they found the specimen of an entire head of a fossil animal, obtained from the coal-fields of Yorkshire, which, from the teeth and other bones, was ultimately referred to the same undescribed genus of sauroid fish.

Having obtained access to this great prize, M. AGASSIZ was then enabled, with advantage, to compare the imperfect relics of Burdiehouse, *first*, with the entire head from the Leeds Museum; and, *secondly*, with a large specimen of the recent *Lepidosteus Spatula*, preserved in the British Museum.

After M. AGASSIZ had, by these various comparisons, established the fact, that the teeth, and certain other osseous remains of Burdiehouse, belonged to a sauroid fish rather than to a sauroid reptile, he considered it as a new genus to which he gave the name of *MEGALICHTHYS*; and to the species found at Burdiehouse (the first which he had seen), he added the name of *Megalichthys Hibberti*.

NOTES TO SECTION X.

Under ordinary circumstances, I might have declined the honour thus rendered me. If I have accepted it, the following reasons may be assigned:

M. AGASSIZ had expressed some little apprehension for any pain which he might inflict in setting me right upon a question regarding which I had publicly expressed

my sentiments. That the apprehension was an unfounded one, I knew but too well, by an appeal to the actual state of my own mind, which admitted no other feeling except admiration for the great talent and discrimination which he had evinced. Under these circumstances, I feared lest my refusal of the compliment which he paid me might be interpreted by him as indicative of any lurking sentiment of impatience under the correction of a misconception, and, consequently, of an unfriendly feeling to the cause of truth and of science.

If I felt any degree of uneasiness whatever, it was in the reflection, that I had, in two instances, been the *sole* cause of others partaking with me in the imperfect view which I had entertained. In the first instance, I was hurt that the misconception had found its way in a work so replete with invaluable facts as that which Mr LYELL has published; and, in the second place, that I should equally have misled another geologist, from whom the most brilliant discoveries in geological science have emanated; I allude to Dr BUCKLAND. But I am convinced that these two individuals possess too enlarged minds not to make a generous allowance for any misapprehension in the case of an animal, which appears, no less in organic structure than in the date of its existence, to have been the very first connecting link between fish and saurian reptiles.

We are, in point of fact, only beginning to be aware, that, in an earlier period of the history of our globe, certain of the largest animals of the waters were endowed with the mixed organization of fish and reptile; that in a later period of the globe, pure reptiles have multiplied; and that the attributes of too many fish and reptiles have been hitherto confounded. M. AGASSIZ has already removed from the class which had been assigned to them, several animals of preconceived reptilian character. Caithness has lost a trionyx, which now proves to be a fish. The chalk of Sussex has also lost another large reptile, which, in a similar manner, turns out to be a sauroid fish of a genus differing from that of Burdiehouse, and possessing a head, jaws, and teeth as large as those of a crocodile ten feet long. "The teeth," M. AGASSIZ writes to me, "are as large as those represented in Fig. 8. of Plate IX."

In short, many saurian reptiles, which were supposed to have lorded it over lesser tribes, have been dismissed from their administration; while an interchange of reptilian and finny attributes has afforded the basis for forming a new natural history cabinet.

Such are the original views opened out to us by the recent discoveries of M. AGASSIZ.

Statements, however, have recently appeared in two consecutive foot-notes appended to the reports of the British Association of Science, and of the Royal Society of Edinburgh, (See the *Edinburgh New Philosophical Journal* for October 1834 and January 1835), that M. AGASSIZ's investigation was not only "confirmatory" of Professor JAMESON's previously expressed opinion upon the animal remains of Burdiehouse, but that myself, as well as other geologists, (not even ex-

cepting the Swiss Naturalist himself), had "adopted" this opinion. In justice, therefore, to M. AGASSIZ, I shall distinctly state, that the only opinion to which I ever yielded was that which constituted the great feature of his own peculiar investigation, viz. that the osseous remains in question of Burdiehouse had disclosed a remarkable character possessed by the larger animals of the carboniferous epoch, which appear to have united in their particular organization the character of fish and reptiles. This view had never before been even "dreamt of in our philosophy;"—it was confirmatory of no other opinion whatever which had been previously expressed;—it originated with M. AGASSIZ exclusively;—it was the only one which had been successfully opposed to my own theory;—and it was the only one ultimately adopted by myself.

Previous to M. AGASSIZ's arrival in Edinburgh, my saurian theory was never opposed upon any other ground, than that the teeth of the Burdiehouse animal were those of a squalus;—which notion, I need not remark, was far more remote from their true sauroid character, than any opinion which I had myself expressed.

As I had distinctly stated at the Sectional meeting of the British Association, my impression that the relics of immense fish existed in the limestone of Burdiehouse, the chief question which remained was with regard to the teeth; and if I had simply named them *sauroid*, instead of *saurian*, I should have kept within the strict limits of correctness. But notwithstanding this approximation to the truth, it was supposed that my theory had fared worse than was really the case. Granting even the affirmative, I would rather see any theory of mine annihilated upon true scientific principles, than survive a different kind of treatment;—in which feeling, I partake with the sentiment expressed by one of MOLIERE's characters, when expatiating upon the systematic rules with which a physician of Paris killed off his patients,—that it would be a less evil to expire under his remedies, than to be cured by those of another person;—for, as it added, although a fatal event occurs, yet a conviction remains that every thing is conducted in order, and according to rule. "C'est une grande consolation pour un defunct."—"Assurément. On est bien-aise au moins d'être mort méthodiquement."

But, happily, my noble sauroid animal,—not exactly a saurian reptile, but an immense sauroid fish,—still holds his sway over primeval waters, the sovereign of the carboniferous epoch.

SECTION XI.—COMPARISON OF SOME OF THE OSSEOUS REMAINS ATTRIBUTABLE TO THE MEGALICHTHYS, WITH OTHERS FOUND AT LEEDS, AND WITH THE RECENT LEPIDOSTEUS.

As the investigation of the osseous remains of Burdiehouse is in a manner only commenced, I merely asked from M. AGASSIZ his opinion regarding such important attributes as the teeth, the

jaws, or the scales. To this information, which he promised to give me after he had instituted a comparison between the Megalichthys of Leeds and that of Burdiehouse, he has added an account of other parts of the anatomy of the animal, the whole having reference to remarks made upon the recent *Lepidosteus*.

M. AGASSIZ's first observations were evidently directed to the dispelling of any possible doubt that the animal of Leeds was a sauroid fish. "The head," he observes, "is most perfect; it is certainly that of a fish, since we see in it the opercular portions, and the branchiostic rays, which only subsist in this class of animals; while behind are the scales of a portion of the trunk. It gives us, then, the greatest possible certainty with regard to the remains in question, as there are in the Leeds specimen many portions in an united state which are only found detached at Burdiehouse."

In reference to the same specimen, a comparison was made with minute bones obtained from Burdiehouse, evidently belonging to one of the fry of the Megalichthys, which had aided in the discovery, that the animal was less a perfect reptile than a sauroid fish. M. AGASSIZ directs attention to the lamellar bone, which is represented in Plate IX. fig. 1, on the side where the indication, fig. 1, appears. He observes, that the lamellar bone, (*plaque*), here seen so distinctly, is the folium, which, in the head of Leeds, covers the space comprised between the branches of the inferior jaw, and which takes the place of the anterior branchiostic rays. On the opposite edge, as may be noted, is a row of maxillary teeth, alternately larger and smaller.

The Structure of the Teeth.—With regard to the teeth of the Megalichthys, M. AGASSIZ states, that in the Leeds specimen they were small, but that upon one of them, which was broken, there was a striated surface characteristic of those of Burdiehouse.

In comparing the teeth collected from Burdiehouse, with those of a specimen of the *Lepidosteus*, several feet in length,

preserved in the British Museum, the latter exhibited teeth of the same size with such as are represented in Plate IX. fig. 6 and 7. They had also the same external structure; they had large plicæ at their base; while the remainder of their surface was otherwise smooth. Some of these teeth, it is added, were sharp at one edge; others were sharp at both edges; while a third description had sharp and projecting edges at their extremity only. As for their interior structure, there was, in all, a conical cavity, more or less elongated, like that of Fig. 7, and it was in the bottom of this cavity that the new teeth were developed upon the old ones falling away.

The Alternation of Large and Small Teeth.—This is the next circumstance to be investigated.

When M. AGASSIZ visited Edinburgh, he had little knowledge of the distribution of large and small teeth in the Megalichthys, except what was derived from the minute specimen of the jaw of one of the fry of the animal, to which I have already adverted. (See Plate IX. fig. 1.) He remarked an evident alternation of larger and smaller teeth, yet it was conceived (as far as such a minute and indistinct specimen could countenance any inference whatever) that there was a greater proportion of large teeth, and that canine teeth were placed upon the whole of the jaw. This notion was again countenanced by the large teeth discovered in an unconnected state, which had been hitherto found more abundantly than smaller ones. An inspection of the Leeds specimen, however, was unfavourable to this notion, inasmuch as there appeared in this instance to be a far greater proportion of small teeth, while the larger canine teeth were chiefly developed in the fore part of the jaw; and hence M. AGASSIZ at first conceived, that there might be two genera of sauroid animals allied to each other, but differing in the comparative size, number, and distribution of their teeth.

While labouring under this uncertainty, and in the absence of any satisfactory specimen whatever from Burdiehouse, there

appeared no other resource left to this indefatigable naturalist, than to inquire whether, in other examples of recent or fossil fish allied to the *Megalichthys*, the larger or smaller teeth prevailed most in number. If the larger or canine teeth should prove to be fewer in number, and should have a more interior and anterior position among the bones of the mouth, he conceived that a great argument would be afforded for assimilating the specimen of Burdiehouse to that of Leeds, whence their identity as one genus of fish, if not exactly established, would at least be a reasonable presumption.

Such a comparison was accordingly instituted, by which M. AGASSIZ came to the conclusion, that in the lesser number of larger or canine teeth, or, in other words, in the far greater proportion of smaller teeth, the sauroid genus of Burdiehouse would be ultimately found to identify itself with that of Leeds, and that thus each animal would be referable to the *Megalichthys*.

This anticipation has been remarkably confirmed in the subsequent discovery of part of a jaw, too late for M. AGASSIZ to see before he left England. It shews a larger tooth alternating with several of much smaller size. The relic (See Plate X. fig. 1) evidently belonged to a young animal, as it exhibits none of the immense and similarly striated teeth which have been found in a detached state. It, however, not only displays a larger tooth alternating with an excess of smaller ones, but likewise a difference of size between the two kinds,—so extraordinary, indeed, as to afford an illustration of the advantages which were to be derived from a comparison of isolated remains, with the connected ones of other animals, at least approaching to one common family.

But I shall now advert to other investigations of comparison. In the recent and very remarkable sauroid fish conceived to be a living type of the *Megalichthys*,—the *Lepidosteus spatula*,—M. AGASSIZ observed phenomena nearly similar. He states that teeth of an inch long, alternate with small teeth which are not a line in length. In this species, he adds, the largest teeth are

found upon the palatine bones; but in other species of the same animal, they rather occur upon the margin of the maxillary bone, and more especially in their anterior part.

And again, in the new genus of *Macropoma* (*Agass.*) of which Mr MANTELL'S *Amia Lewesiensis* is considered as the type, and of which M. AGASSIZ professes he is not acquainted with any living species, a similar alternation was observed. Teeth of very different sizes occurred, always smaller on the edge of the jaw bones, and proportionally very large upon the internal bones of the mouth, so that it would have been difficult to conceive that the fragments shewing a series of palatine teeth, or those shewing a series of maxillary teeth, had belonged to the same fish, if they had not been found united in other examples.

These were the instances of analogy by which M. AGASSIZ, in the first instance, proposed to explain the difference in the size of the teeth which are distributed along the jaws of the *Megalichthys*, and from which he inferred that a similar disposition might prevail in the Burdiehouse animal. His anticipation, as I have remarked, was singularly confirmed.

It has been at length shewn that in the *Megalichthys* very large teeth have coexisted with very small ones; but as they severally exceed so much in magnitude those of the recent *Lepidosteus*, our admiration is greatly excited in contemplating the enormous sauroid fish of a former world.

The larger teeth of Plate IX. fig. 2 and 10, have a breadth at their base of $1\frac{1}{2}$ to 2 inches, and a length of nearly 4 inches.

After having explained the teeth and their distribution, I now proceed to the scales of the *Megalichthys*.

One description of scales exhibits a coating of enamel of a nut-brown colour, and often of the most brilliant lustre imaginable. These scales are of various forms, as may be seen in Plate VIII fig. 3 to 5, and Plate XI. fig. 2 to 8. They are generally angular. A curious character is the punctured surface, which many of these

scales display,—a character which I have traced, though in a less prevalent degree, in the scales of the recent crocodile.

It is remarkable that M. AGASSIZ, from his observation on the sauroid fish of Leeds, unites the character of certain large angular scales, which present a punctured appearance, with the character displayed by certain bones of the head, which, in an isolated state, possess very irregular forms, but which have a surface of the same kind as that exhibited by the scales. To such bones he refers all the elongated portions collected at Burdiehouse possessing such a character; and, in recommending that the Royal Society of Edinburgh apply for a cast of the head of the *Megalichthys* preserved in the Leeds Museum, he adds,—“ You will see in the largest of the Leeds specimens, many portions united which are only found detached at Burdiehouse. The surface of these bones is enamelled and punctured in the same manner as in the larger scales of Burdiehouse, and this trait is again developed in the bones of the cranium, of the face, of the thoracic cincture, and of the branchiostegal lamellæ, exactly in the same manner as is shewn in the plates of scales, as well as in all the detached maxillary and thoracic bones found at Burdiehouse. It can therefore no longer be doubted, that all these portions are referable to the same animal.”

These remarks upon the scales of the *Megalichthys* form the communication which I have received upon the subject from M. AGASSIZ.

A chemical estimate has been recently made of these relics in reference to the scales of the *Lepidosteus*.

The scales of the *Lepidosteus*, which struck me as being so like those of the Burdiehouse animal, had not suggested any particular observations of comparison; their mutual similarity, except perhaps in some few circumstances of form, being so evident. As far, however, as relates to analysis, a gentleman of profound chemical knowledge, Mr ARTHUR CONNELL of Edin-

burgh, has had his views directed to this subject, as, indeed, to other comparative inquiries of the same nature, relative to the change which animal remains of so early a geological date as those of Burdiehouse have experienced. His valuable memoir on this subject will appear in the present volume of the Transactions of the Royal Society of Edinburgh.

I have been favoured by Mr CONNELL with the result of his examination of the scales of the Megalichthys, which he has subsequently compared with an analysis given by CHEVREUL of the scales of the recent Lepidosteus. These two results, with the view of comparison, I have arranged in a tabular form.

M. CHEVREUL'S ANALYSIS OF THE SCALES OF THE RECENT LEPIDOSTEUS.		ANALYSIS OF THE SCALES OF THE FOSSIL MEGALICHTHYS, BY A. CONNELL, ESQ.	
Phosphate of Lime,	46.20	Phosphate of Lime, with a little Fluoride of Calcium,	50.94
Carbonate of Lime,	10.	Carbonate of Lime,	11.91
Phosphate of Magnesia,	2.02	Phosphate of Magnesia, <i>trace</i>	
Carbonate of Soda,	.10	Potash and Soda,	.47
Gelatinous Animal Matter,	41.10	Animal Matter, <i>trace</i>	
Fatty Matter,	.40	Siliceous Matter,	33.10
		Water,	3.48
			36.58
		Bituminous Matter,	.12
	99.82		100.02

Upon the assumption that the scales of the recent Lepidosteus and those of the Megalichthys identify themselves with each other, as far as external character and consistence are concerned, the foregoing Table of chemical comparison is a most important and instructive one.

With regard to the earthy ingredients of the phosphate of lime and carbonate of lime, it will be seen at first view, that, in both the fossil and recent animals, they constitute about three-fifths of the solid matter of the scales. In the fossil animal, they have remained in a proportion, most probably, unalterable.

In Mr CONNELL's analysis, a little fluoride of calcium appears.

The phosphate of magnesia, along with potash and soda, or the carbonate of soda, appear in very small proportions in both the fossil and recent animals.

Gelatinous substance, with a very trifling quantity of fatty matter, amounting together to somewhat less than one-half of the materials contained in the scales of the recent *Lepidosteus*, has almost entirely disappeared. In the fossil animal, Mr CONNELL could detect nothing more than a trace of animal matter.

But the place of the animal substance has been supplied in the scales of the fossil fish, by nearly thirty-seven parts in a hundred of siliceous matter, in which is included a little combined water. These foreign ingredients have no doubt been derived from the matter in which the scales have been entombed. In the present instance, they evince the solubility of silex, under certain circumstances, and its important geological character as a replacing substance.

From this interesting comparison, I now pass on to the rounded scales of the *Megalichthys*.

The Rounded Scales.—M. AGASSIZ has conceived that no doubt whatever can be supposed to hang over any of the bones which he has hitherto considered. Regarding one class of relics, however, perhaps some little degree of obscurity may remain. The rounded scales of the *Megalichthys* are indicated by an internal cancellated, and by an external lamellar structure, as well as by an absence of the shining enamel so distinctive of the angular scales. A representation is given of them in Plate VIII. Fig. 2.

Some of the rounded scales appear to be finely fringed at their edges. (See Plate X. Fig. 2.)

In Plate X. Fig. 3, a representation is given of these scales in a state of contiguity. M. AGASSIZ, from an examination of them, conceives that they are imbricated.

The rounded scales are of various sizes. I have seen speci-

mens of them attaining the diameter of five inches ; but, in proportion to their great magnitude, they appear to grow thinner.

It is supposed by M. AGASSIZ, that these relics will meet with an explanation in the Plate of scales given of the *Lepidosteus* in the first volume of his "*Recherches sur les Poissons Fossiles* ;" and that they are referable to such dorsal scales as are to be found at the top of the long series which traverse the Plate, given by him in Vol. ii, Tab. B.

With these observations, the communication with which I have been favoured by M. AGASSIZ relative to the sauroid remains of Burdiehouse, is concluded. Some few additional observations from the same eminent naturalist, (See the *Edinburgh New Philosophical Journal* for January 1835), on the comparative character of the large sauroid fish of early and more recent formations, will properly close the present inquiry.

He states, that it is in the deposits below the lias that we begin to find the largest of those enormous sauroid fish, "the osteology of which recalls in many respects the skeletons of saurians, both by the closer sutures of the bones of the skull, by their large conical teeth striated longitudinally, and by the manner in which the spinous processes are articulated with the body of the vertebræ, and the ribs at the extremity of the spinous processes."

It is likewise remarked, that "we do not find fish decidedly carnivorous before the carboniferous series ; that is to say, provided with large conical and pointed teeth. The other fish of the secondary series before the chalk appear to have been omnivorous ; their teeth being either rounded, or in obtuse cones like a brush."

I cannot sum up this portion of the investigation, without adverting to the geological importance of selecting for purposes of comparison and analogy, of which the *Lepidosteus* affords a splendid example, animals subsisting in recent times, which may

be supposed to have the nearest relationship to races long since extinct. In the present instance, it has been reserved to the talents and discrimination of an AGASSIZ alone, to rescue from a kind of obscurity a sauroid fish, (I was nearly repeating the term of a *finny reptile*) dwelling among the lakes and rivers of the most thermal regions of America, and to render it elucidative of one of the earliest states of our globe, when, in the language of this naturalist, fish combined in their peculiar organization the character of reptiles;—of a class of animals, which only appeared in great number during a later period of the history of our planet.

NOTES TO SECTION XI.

In closing M. AGASSIZ's account of the *Megalichthys*, I feel it my duty to express the deep sense of obligation I am under to him for correcting the imperfect views which I had entertained regarding this animal. But it is not the gratitude of an individual like myself that will form the meed which awaits this naturalist. The general cause of geology is interested in the light which he has thrown upon the subject of Palæontology.

Considering the very disjointed state of the specimens hitherto collected at Burdiehouse, no feeling can possibly remain, except one of admiration that M. AGASSIZ has been enabled to make so much of them. It is greatly to be lamented, that this naturalist had not, before he returned to Switzerland, the opportunity of studying some jaws of the *Megalichthys* which had assuredly turned up, but the sight of which was never allowed to extend to the Royal Society, or to myself.

It was in the eleventh hour that I came into possession of part of a jaw, which was, I believe conceded to me, from motives of compassion. It was considered hard, that he who had first pointed out the treasures of the quarry should not be permitted to avail himself of one of the relics which he most coveted. I am sorry that it had arrived too late for a drawing of it to be forwarded to M. AGASSIZ, in time for his remarks upon its striking osteological character.

SECTION XII.—OTHER LOCALITIES IN WHICH THE REMAINS OF THE MEGALICHTHYS HAVE BEEN FOUND.

It becomes an interesting object of inquiry if the remains of the *Megalichthys* have been found in other localities.

The result of the information that I have been able to obtain is, that such remains have been discovered in the coal-fields of

the neighbourhood of Glasgow, and in the districts of Cupar, Errol in Perthshire, East Calder, and Musselburgh; also in the coal-fields of Northumberland, of Yorkshire, and of North Wales. It amounts only to a probability, that remains of the *Megalichthys* have been found in certain limestones of Ashford, in Derbyshire, and of Northumberland. The details of these discoveries are given in the note appended to this section.

M. AGASSIZ has stated his opinion, that there exists in Scotland another species of *Megalichthys*, of which some relics were placed in his hands by Mr ROBISON, who had procured them from Greenside near Glasgow. He conceives that the animal to which they may be referred, is to be distinguished from that of Burdiehouse by the form of the teeth, which is more compressed and very sharp at the edges. He proposes to call it the *MEGALICHTHYS FALCATUS*.

NOTES TO SECTION XII.

If it be allowable to suspect that the scales of the *Megalichthys* have been mistaken for those of saurian reptiles, as was the case in the first instance at Burdiehouse, the evidence with regard to other localities in which the remains of the *Megalichthys* have been found, becomes multiplied.

The black limestone, as it is called, of Ashford in Derbyshire, so named from the bituminous matter which is diffused through a great part of it, rather affords evidence of its having been the deposit of an estuary than of a fresh water river, or lake, such as the limestone of Burdiehouse is supposed to have been. This fact I shall endeavour to substantiate hereafter. It is sufficient at present to state, that the limestone of Ashford contains, along with marine shells and corallines, various remains of the plants common in coal-fields.

In this limestone Mr WHITEHURST, who wrote his well known *Theory of the globe* in the year 1778, found, as he stated, the impression of a crocodile. Mr WHITE WATSON of Bakewell conceives that Mr WHITEHURST mistook for these remains a large orthoceratite; but, with all due deference to my old acquaintance, I am inclined to doubt the legitimacy of this explanation, from having myself lately ascertained that remains of very large fish existed in this limestone, which, if not of the *Megalichthys*, assimilated themselves to other remains found at Burdiehouse;—this being a fact which had been previously unknown. It seems then at least a plausible conjecture, that some remains of a large sauroid fish might have turned up in this locality.

This suspicion meets with additional support from a passage which we find in

the "View of the present state of Derbyshire" (vol. i. p. 200), written by PILKINGTON in the year 1789. The writer not only affirms that a small alligator was found entire in the black marble of Ashford, but he also adds that another specimen, the tail and back of a crocodile, had been discovered in the same locality, and had met with preservation in a cabinet at Brussels.

But it is time to advert to statements better verified.

In the year 1793, the Rev. DAVID URE wrote his History of Rutherglen (a most interesting work), in which it is certain that he discovered part of a jaw and teeth, which, from the drawing given of them (plate 19 of his work), are referable to the Megalichthys. They are said to have been found among schist in the quarries of Philipshill, and in the till above coal at Stonelaw. (*See p. 330 of the work*). Other remarkable teeth will also be found described in his work.

In the year 1830, Dr FLEMING published an account of scales, and of a tooth which evidently belonged to the Megalichthys. They were found in the yellow sandstone of Drumdryan quarry to the south of Cupar, and in the red sandstone of Clashbinnie near Errol in Perthshire (*Edinburgh Journal of Natural and Geographical Science*, vol. iii. p. 81.)

During the same year, viz. in A. D. 1830, Mr LYELL, in his Principles of Geology, states, that the Rev. VERNON HARCOURT discovered in the mountain limestone of Northumberland a saurian vertebra. Whether this relic may be referred, or not, to the Megalichthys, remains to be determined.

In December 1833 my discovery took place of the Megalichthys of Burdiehouse.

Also in 1833, there was figured in the Fossil Flora of Professor LINDLEY and Mr HUTTON some remarkable relics, which, under an impression, acknowledged at the time to be a very dubious one, that they might be identified with some fungus, suggested the name of Polyporites Bowmanni. They were discovered by J. E. BOWMAN, Esq., of the Court near Wrexham, among the ejected shale of a coal-pit near the entrance of the vale of Llangollen in the County of Denbigh (*Fossil Flora*, plate 65). Although the writers of the Fossil Flora have proposed the name of Polyporites Bowmanni, indicative of a vegetable fungus, it is with proper caution remarked, that "it is a matter of great doubt whether these relics actually belong to the vegetable kingdom;" and they admit with Mr BOWMAN, that one of his specimens "might be taken for the scale of a fish, or of some great saurian reptile." Now I have little or no doubt whatever in my mind, that these relics are the round scales of the Megalichthys. It is stated at the close of the communication, that it may be worth considering "whether the Carpolithes umbonatus of STERNBERG, referred with doubt to Cyclopteris by ADOLPHE BRONGNIART, may not also be something of a similar nature."

In 1834, Mr WITHAM of Lartington obtained from the limestone of East Calder some scales of the Megalichthys. Mr ROBISON procured some teeth from Greenside, near Glasgow, of the Megalichthys falcatus (AGASS.), and Lord GREENOCK made the highly interesting discovery, that the remains of the Megalichthys were entombed in a seam of coal and bituminous shale at Stoneyhill, near Musselburgh, along with various other relics.

During the same year (1834) scales of the *Megalichthys* were shewn to me by W. C. TREVELYAN, Esq. of Wallington, which he had obtained from the coal-fields of Northumberland.

As these remarks conclude my account of the *Megalichthys*, I may here mention the information which M. AGASSIZ communicates to me, that in the much newer formation of Whitby and Scarborough, he has found the fragments of a fish which even exceed in size those of the Burdiehouse animal; some of the portions of the cranium being nearly two feet in diameter. In announcing to me the discovery of this monster, he adds, "After having seen so many extraordinary and surprising things in the monster of Whitby, which exceeds the largest *Ichthyosaurus*, I perceive that I am still only commencing the preface of a book, which future years will supply with the wonders of the sea. And I shall think myself happy if I can only have excited interest for a study, which is still so difficult for want of terms of comparison sufficiently numerous."

SECTION XIII.—THE GENUS OF PYGOPTERUS BELONGING TO THE SAUROID FAMILY.

While the primeval waters of the carboniferous epoch had their larger sauroid monsters, they had also lesser sauroid tributaries, one of which was in the form of the *Pygopterus*, belonging to the same family as that to which the *Megalichthys* has been referred.

M. AGASSIZ has favoured me with the following description of the *Pygopterus* of Burdiehouse. Unfortunately, however, it only applies to a fragment of the fossil fish, which is represented in Plate VII. fig. 2.

The proportions of the rigid tail of the animal, the relative position of the dorsal and of the anal fins, the form of the fins, which are horizontally and perpendicularly elongated, as well as the considerable number of rays which compose them, serve to point out the posterior part of a fish of the genus *Pygopterus*, which belongs to the "*Sauroides Heterocerques*," (AGASS.) Amidst the numerous fragments of bones of the head, as well as of the thoracic cincture, which have been found along with them, it will remain for a detailed description to explain, by the system of exclusions, what might have belonged to the animal. M. AGASSIZ then conceives, from his having seen so many heads of the *Pygopterus*,

as well as the head of the *Megalichthys* of Leeds, that the identification will not be insurmountable.

This relic was the first which I discovered at Burdiehouse; for which reason I have requested M. AGASSIZ, that, in its specific name, I may be allowed to dedicate it to a geologist for whom I possess the greatest esteem. He has accordingly obliged me by sanctioning the name of *Pygopterus Bucklandi*.

M. AGASSIZ conceives that the best specific character of the *Pygopterus Bucklandi* is the relative smallness of its scales.

SECTION XIV—THE REMAINS OF THE FISH OF THE PLACOIDIAN ORDER
DISCOVERED AT BURDIEHOUSE.

It has been explained, that Placoidian fish are easily known on account of the irregularity manifested by the solid parts of their integuments, which consist of materials of enamel sometimes considerable, and sometimes reduced to little points; as is shewn in the tubercles of Rays, or in the different chagrins of *Squali*, &c.

The same naturalist, at the commencement of his great work, has expressed his imperfect knowledge of the fossil fish of this order. But I believe that since his recent visit to Great Britain, he has been enabled to examine some few specimens in comparatively a better state of preservation. He conceives, that, in correspondence with differences of organization, such remains of fish as are found in beds anterior to the carboniferous group, would have to be referred to the order of Placoids.

M. AGASSIZ has recently stated, that, among the Placoids, those above all predominate which have their teeth furrowed in both the external and internal surface, and have large thorny rays.

These large rays are now considered as the supports of the dorsal fins of several genera, which, from their approach to the Cestracion of New Holland, M. AGASSIZ has formed into a distinct family, under the name of *Cestraciontes*, to which family six fossil genera, approaching to the *Squalus*, with rays differing considerably from each other, have been already assigned.

M. AGASSIZ remarks of this family, that it only comprehends one genus of actual creation, the genus *Cestracion*; the others being fossil; that the *Hybodontes* (AGASS.) are equally fossil. Then follow the *Squali*, the *Rays*, and the *Cyclostomæ*.

The limestone of Burdiehouse entombs thorny rays of immense magnitude, and most beautifully configured, which it is impossible to contemplate without amazement. (See Plate XI, fig. 1, A, B, and C.) The drawings of them given in Plate XI. are upon a scale of one-half only of their original dimensions. They are treble the size of a recent dorsal ray, obligingly shewn me by Mr CLIFT of the Museum of the Royal College of Surgeons, which was supposed by M. BLAINVILLE to be the dorsal bony ray of a large *Silurus* of the Ganges.

M. AGASSIZ confesses that he knows of no other relics found elsewhere to which they bear any resemblance;—that, while the mountain limestone, the lias, the oolite, and the chalk formation, afford some very striking and decided genera, none of them resemble the rays found at Burdiehouse, which he thinks ought to be referred to a separate genus of the family of *Cestraciontes*. He proposes to name the fish to which these rays belong the *Gyracanthus formosus*.

It is most unfortunate that nothing is known of the *Gyracanthus formosus* more than is indicated by these relics, which give the promise of a fossil monster some time or other turning up, equalling, if not surpassing in interest, the *Megalichthys*.

The teeth, even of the *Gyracanthus*, are unrecognised. “It is not impossible,” says M. AGASSIZ, “that the teeth of so remarkable an appearance, which have been discovered, may belong to this animal. But this is a mere supposition, solely founded upon the analogy of what I have seen concerning the rays of other formations.”—I may here observe, that the teeth alluded to were not found at Burdiehouse, but in the important fossiliferous coal-seam of Stoneyhill near Musselburgh, first brought to notice by the researches of Lord GREENOCK.

Besides the rays which have been assigned to the *Gyracanthus*, there exists a peculiar kind of *Ichthyodorulite*, comparatively small, and of an elegant form. But as so much more information is demanded relative to the placoidian animals to which they belong, any drawings of them may be properly suspended until further remains turn up.

I have now to state a very important analysis, undertaken by Mr A. CONNELL, of the bony rays of the *Gyracanthus formosus*:—Phosphate of Lime with a little Fluoride of Calcium, 53.87; Carbonate of Lime 33.86; Siliceous matter 10.22; Potash and Soda, partly as chlorides, 0.71; Bituminous matter 0.54; Phosphate of Magnesia, a trace; Animal matter, a trace: Total 99.20.

NOTES TO SECTION XIV.

Mr CONNELL has compared the analysis which he has given of the bony rays of the *Gyracanthus formosus* with one by M. DUMENIL of the bones of the recent pike. I shall throw these two analyses into a tabular form, for the sake of a more ready comparison.

ANALYSIS OF THE BONES OF THE PIKE, BY DUMENIL.		ANALYSIS OF A THORNY RAY OF THE GYRACANTHUS FORMOSUS, BY ARTHUR CONNELL, ESQ.	
Phosphate of Lime,	55.26	Phosphate of Lime, with a little Fluoride of Calcium,	53.87
Traces of Soda, and loss, . . .	1.32	Phosphate of Magnesia,	trace
Animal Matter,	37.36	Potash and Soda, partly as Chlo- rides,	.71
Carbonate of Lime,	6.16	Animal Matter,	trace
		Carbonate of Lime,	33.86
		Siliceous Matter,	10.22
		Bituminous Matter,	.54
	100.10		99.20

If it be allowable to suppose that there was any original approximation in the quality and quantity of chemical ingredients severally possessed by the bones of the pike and the fossil thorny rays of the *Gyracanthus*, which is rendered very probable by the proportion of phosphate of lime in each so nearly agreeing, the one analysis yielding 55.26 parts, and the other 53.87 parts in a hundred,—the following observations occur.

The fossil thorny rays contain a trace only of phosphate of magnesia, which has not been detected in the bones of the pike.

There is a small proportion of soda in the recent bones, and perhaps a less proportion of potash and soda existing partly as chlorides in the *Gyracanthus*.

The proportion of animal matter in the bones of the pike amounts to as much as 37.36 parts in a hundred, of which a trace only appears in the *Gyracanthus formosus*.

Having stated these differences, I shall first make some remarks on the great quantity of phosphate of lime possessed by the fossil ray.

Mr CONNELL has very properly remarked to me, in reference to the *Gyracanthus* having been assigned to the family of the Cestraciontes, that the Cestracion is considered as a cartilaginous fish, whilst the great quantity of bone-earth contained in the dorsal ray of the fossil animal, amounting to 54 per cent., is incompatible with the notion of its being any thing but bone. Now, I certainly find it remarked of cartilaginous fish, that, while the skeleton of these animals remains constantly cartilaginous, in rare cases only it contains osseous fibres; the calcareous matter being in such instances deposited simply in the form of small grains. There are, at the same time, certain fish of this class, though appearing to separate themselves from it, as, for instance, the orders of Chismopnea and Telebranchia, among which the skeleton is fibrous, and becomes with age perfectly osseous.

To such a structure, therefore, I would refer the fossil dorsal rays of the *Gyracanthus*, which appear to have been formed of osseous fibres, disposed in a longitudinal manner (as can even be traced in their mineralized structure), the intervals or pores having been originally filled with animal matter. This arrangement of structure is indeed remarkably shewn in some fossil specimens, where elongated pores, or tubes, larger than common, are filled with siliceous matter.

Another remark is suggested by the mode in which the loss of animal matter has been supplied in the fossil rays of the *Gyracanthus*. It would here seem, that the bones of the pike contain, in addition to the phosphate of lime, about six parts in a hundred of the carbonate of lime. Now, it is remarkable that the fossil thorny ray contains as much as 34 parts nearly of the carbonate of lime, along with only 10 parts of siliceous matter, by which it appears that the loss of animal matter has been very readily supplied by infiltrations of calcareous matter, derived no doubt from a calcareous matrix, but comparatively little with siliceous matter. Ought this circumstance to throw any light upon the original organization of these rays?

There is, at least with myself, much difficulty in explaining why the loss of animal matter is chiefly supplied in these fossil rays by carbonate of lime, which is exactly the reverse of what appears to have taken place in fossil scales. Whether, in this instance, the animal matter has been sooner released from the substance of the bone, and, as a consequence, its place more directly supplied by infiltrations of calcareous matter from the matrix of these relics, I will not pretend to determine. In the dense and compact structure of the bony scales of the *Megalichthys*, the mineralization might have gone on far more slowly; and hence the substitution of a great excess of siliceous matter.

The two different characters of mineralization are exhibited in the following Table.

<i>Fossil Scales of the Megalichthys contain</i>		<i>Thorny Rays of the Gyracanthus contain</i>	
Carbonate of Lime, . . .	11.91	Carbonate of Lime, . . .	33.86
Hydrated Siliceous Matter, . . .	36.58	Siliceous Matter, . . .	10.22
	48.49		44.80

These observations have been suggested by the important analysis of Mr CONNELL. But he is far better qualified than myself to enter into questions relative to the chemistry of geology.

I shall, lastly, make some few remarks upon these large rays, as they are found in other localities.

It would appear that the large bony rays of the Gyracanthus are not confined to the limestone of Burdiehouse, as I have seen specimens of them collected from the argillaceous shale of Fifeshire. Similar relics have also been discovered in Northumberland.

In the next place, large bony rays, referable to other placoidian fish, appear in the shale of the coal-fields of Glasgow; they are likewise found in limestones of marine origin, as in the mountain-limestone of Ashford, from which locality I procured them during the course of the last summer. Dr SIMPSON of Bathgate found a sili-
 cified organic substance in a mountain-limestone of marine origin, which, if it had not been in so old a deposit, I should have taken for a belemnite. It was obtained from Kate Shield's or Crawford's quarry, near Bathgate. M. AGASSIZ thinks that it indicate an interior cavity (from which the organic matter must have been removed) of one of these large rays.

SECTION XV.—THE COPROLITES OF THE LIMESTONE OF BURDIEHOUSE.

From the numerous relics of small and immense finny animals discovered in the quarry, it cannot surprise us to find that foecal remains should occur in an abundance, rivalling perhaps in this respect the particular locality which very early excited the attention of Dr BUCKLAND, and to which he has given the name of the Cloaca maxima of Gloucestershire.

In inspecting the very exact figures of the coprolites which have been published in the excellent memoirs of Dr BUCKLAND on this subject, it might be expected that we should find these shapes abundantly developed in the limestone of Burdiehouse; but the contrary is the fact. The peculiar forms of the foecal contents of the intestinal canal must, from their aqueous submer-

sion, have been frequently lost. Although coprolites containing the indigested scales of fish are most abundantly diffused through the limestone, they seldom preserve any decisive form.

An exception to this rule certainly occurs in the argillaceous shale lying above the limestone, indicative of a difference of circumstances by which the form of the coprolites has been preserved. This deposit was no doubt originally a turbid one, calculated to obviate the washing away of any faecal shape.



Two representations of the smaller coprolites are here given. Their form is far better preserved than that of larger specimens.

The larger coprolites attain a great size. I have seen them occasionally diffused over a surface of limestone to the extent of nearly a foot.

These faecal remains are of a pale yellow colour, and have a very dull earthy aspect. In the shale they acquire a darker tint.

Mr CONNELL has undertaken an analysis of these coprolites, which he has accomplished with his usual skill. Two of these I shall subjoin.

	First contains	Second contains
Phosphate of Lime, with a little Fluoride of		
Calcium,	85.08	83.13
Carbonate of Lime,	10.78	15.11
Silica,	.39	.29
Potash and Soda,	.59	
Bituminous matter,	3.95	1.47 { with alkaline matter.
Phosphate of Magnesia, a trace.		
Animal Matter, a trace.		
	100.79	100.

Another analysis of a Burdiehouse coprolite has been recently published by Dr WILLIAM GREGORY and Mr R. WALKER; but as the specimen was unfortunately mixed with foreign matter, as, for instance, with the sulphuret of iron, the result would rather mislead. These gentlemen have, however, conducted a

very satisfactory analysis of a coprolite found in Fifeshire. (See Edinburgh New Philosophical Journal for January 1835.)

The most important information yielded by these coprolites, points to the means of support and habits of the animals which lived during such a remote epoch.

In the smallest description of coprolites, we see, with few exceptions, little more than a homogeneous mass. A question then arises with regard to the support of such immense shoals of smaller fish as appear to have frequented this locality. These must have formed objects of pursuit for larger monsters whose remains are here collected.

In this inquiry I shall recur to the Entomostraca which formed the subject of our early inquiry.

That calcareous springs, such as must evidently have been in play when the deposit of Burdiehouse was formed, should have been favourable to the growth of the myriads of microscopic minute animals which occupied the waters of this ancient river, or lake, I need not remark, as the nature of their testaceous coverings points to the medium in which they subsisted.

The inquiry, then, which is suggested, has a reference to the existence of these Entomostraca as the food of the smaller finny inhabitants of ancient waters.

The existence of these microscopic races assuredly finds some analogy with what has been recorded by an excellent naturalist regarding the modern waters of Lochmaben in Dumfriesshire. Entomostraca abound in this fresh-water lake about seven-twelfths of a line in length, which are supposed to approach nearest to the *Lynceus lamellatus* and *Trigonattus* of MULLER. They breed very frequently throughout the year, and carry the ova about with them, as is the habit of most crustaceous animals. (See *Dr Knox's Memoir in the Transactions of the Royal Society of Edinburgh*, vol. xii. page 505.)

Until the appearance of Dr KNOX's instructive paper on the habits of the Vendace (the *Corrigenus* of systematic writers),

which was afterwards extended to those of the herring and salmon, the importance of entomostraca, as an object of the food of many fish, was either unknown or lost sight of; and the popular opinion regarding the vendace of Lochmaben, long entertained, was, that, "cameleon like," they derived support from the medium in which they existed. But Dr KNOX shewed that more solid matter was demanded for the food of these fish, and that the microscopic entomostraca diffused through the waters of Lochmaben served as the food of the vendace, affording them a rich, and, at the same time, a most delicate bait, for which they refused every other kind of food, and, consequently, were not to be captured by the line.

In judging, then, from analogy, it is not an unreasonable supposition, that the abundance of microscopic animals contained in the calcareous deposit of Burdiehouse might, like the modern Entomostraca of Lochmaben, have stood in a similar relation to certain of the smaller fossil fish which have been described, in having afforded them the abundant means of sustenance.

But if this analogy may reasonably explain the kind of support afforded to some of the smaller fish, it fails of application when we come to larger kinds.

In proportion as coprolites increase in size, we find that they contain the scales of fish, shewing that the larger fish to which these foecal remains are referred, must have frequented the ancient river or lake, indicated by the limestone of Burdiehouse, in quest of their prey. Many of the indigested scales are of smaller fish, but in some of them I have found larger scales, as well as fragments of larger bones, shewing that the *Megalichthys* might have even lived upon its own progeny.

But, as a contemporaneous fish of extraordinary magnitude, the *Gyracanthus formosus*, must have likewise frequented these ancient waters, it is not always easy to make very accurate coprolitic distinctions.

Another kind of food afforded to the lesser finny inhabitants of primeval rivers or lakes, must of necessity have consisted in the droppings from larger animals, or even in the putrid carcasses of such fish as died in the waters. In these cases, numerous little scavengers (as Dr BUCKLAND calls them) would not allow putrid and insalubrious matter to remain long undevoured.

It would thus appear, that while the impurity of ancient waters was thus obviated, an excess of increase was checked by a mutual system of voracity.

NOTES TO SECTION XV.

M. AGASSIZ writes to me, that he has been making observations on the organs of digestion possessed by the large monsters belonging to later formations. He found that a very singular body, which Mr MANTELL had taken for the swimming bladder of the *Macropoma*, was in reality its stomach, the different membranes of which were well preserved, yet were liable to exfoliation when long in contact with the air. At the posterior extremity of the alimentary tube, coprolites might be detected, round, like those of the reptiles of Lyme Regis, and containing scales of the *Zeus Lewesiensis*. "Who would have formerly presumed," he asks, "to one day find in the fossil state organs of digestion with all their forms preserved?"

SECTION XVI.—THE MODE IN WHICH VEGETABLE AND ANIMAL REMAINS ARE DIFFUSED THROUGH THE LIMESTONE OF BURDIEHOUSE.

The sequel of this portion of the present memoir will be devoted to a few remarks on the mode in which the vegetable and animal remains of Burdiehouse are diffused through the limestone.

In this diffusion, little or no order is preserved. Vegetable and animal remains are not confined to particular seams of the rock, but may occur in any part of it. Nor are they confined to the limestone itself, since they have been found in argillaceous and bituminous shale, both above and below the bed. And if they are discovered in much greater number in the limestone, the excess may, in some little degree, be owing to the far better state of preservation in which organic remains are preserved in a calcareous matrix. At the same time, the circumstance must not be lost sight of, that ancient waters, in which calcareous matter was

elaborated, seem to have been more favourable to the development of animal life than any other medium.

One observation, however, I have not unfrequently made, which is this: that in portions of the limestone remarkable both for the quantity of entomostraca, as well as diffused vegetable matter which they contain, numerous remains of fish are not unfrequently found. In Plate VII. fig. 6., for instance, is a fragment which includes, along with microscopic entomostraca, the vegetable remains of the *Lepidostrobus*, and the fish to which the name has been assigned of *Palæoniscus Robisoni*.

SECTION XVII.—THE ACQUISITION OF ORGANIC REMAINS WHICH MAY BE EXPECTED DURING THE PROCESS OF QUARRYING.

I have at length described the mineral character, and the various organic remains enclosed in the freshwater limestone of Burdiehouse; its plants; its entomostraca; its smaller fish; the entombed relics of its larger monsters, the scaly *Megalichthys*, and the *Gyracanthus formosus*, the latter armed with immense and beautifully configured rays.

An investigation of the rich treasures of the quarry is only at its commencement. From the multitude of vegetable remains which every explosion of the quarry brings to light, the limestone appears as if it had been destined to enclose a whole grove which had existed of *Lycopodiaceæ*, and other kindred plants, beset with a dense undergrowth of smaller ferns. Under these circumstances, a rich field must surely await the fossil botanist.

Nor is the field of research less promising to the entomologist who has leisure to study the countless entomostraca with which the deposit, in its original state, must have almost seemed alive. Although many genera or species may be detected, only three have been yet noticed, chiefly on account of the less complex character which they display.

But the great treasures of the quarry consist in its vertebral animals. Upon the valuable additions to fossil ichthyology,

which, from this source, may be expected, I will not enlarge. Its fish, though numerous, are known to us by very few specimens; and, as for its gigantic monsters, we are hitherto only enabled to judge of them by broken relics: *Ex pede Herculem*.

Great, however, as is the satisfaction from contemplating the riches of the deposit of Burdiehouse, it is impossible that this feeling should not be alloyed, in some degree, by the recollection that these limestone quarries had been worked for perhaps half a century, or more, at no greater distance from Edinburgh than four short miles; and that, during this period, countless bones, to the irreparable injury of science, must have been sacrificed on the fires of the adjacent limekiln.

If we would form some little, yet at the best a very inadequate, notion of the extent of this continued destruction of osseous fragments which must have been going on throughout a very prolonged period of time, we must descend into the caverned chambers which constitute the old workings of the quarry.

The old line of Burdiehouse quarries was, in the earliest stage of its sinkings, so wrought as to present to view a deep perpendicular escarpment; which is the state of the newer quarry at present. The strata of limestone, which are conjointly twenty-seven feet in thickness, dip towards the south-east, at an angle of 25° . Now, in order to extend these workings by deep excavations, immense square pillars, wrought out of the rock, have been allowed to remain, as the supports of a roof formed by the upper stratum of the limestone, which roof, in its turn, sustains a great thickness of superincumbent shale.

These excavations are of considerable extent, greater even than is rendered manifest. The quarry, which was originally laid dry by an engine, became converted, upon its abandonment, into a reservoir intended to contain the drainage-water, conducted by subterranean channels, from a more elevated quarry of freestone. Consequently, long-extended chambers lie concealed beneath the

deep waters, which pervade the intricate recesses of this spacious grotto.

From this vast submerged labyrinth, formed during the process of quarrying, myriads of organic remains have, for fifty years or more, been extracted,—only to be devoted to the kiln!

But this destruction is not without a precedent.

When I accompanied a savant to the older excavations of Burdiehouse, he pronounced the quarry, as well in reference to its picturesque character as to the associations which it instantly inspired,—A SECOND MONTMARTRE.—(See *Plate V.*)

The famous Gypsum quarry of Paris certainly exhibits an analogous instance of a prolonged destruction of organic remains, which was not effectually resisted, until a CUVIER, supported by all the aid which a government friendly to science could impart, interfered, and, with the arm of power, stopped a ruthless annihilation of organic remains fatal to our knowledge of the tertiary history of our planet.

In the present instance, the merit of a similar interposition, which Geology will ever commemorate with gratitude, is due to THE ROYAL SOCIETY OF EDINBURGH.

NOTES TO SECTION XVII.

In admiring the picturesque character of the old quarry grotto of Burdiehouse, the imagination is liable to be carried beyond the precincts of sober philosophical meditation, and, in reference to the osseous relics enshrined within its solid walls, to even indulge in the phantasies which geology can but too readily conjure up. Nothing seems wanting to complete the illusions which the grotto is calculated to excite, except to connect them with an imaginary emergence from beneath its dark watery recesses of the GENIUS OF FOSSIL HISTORY,—the same Genius who has given inspiration to a WOODWARD, a CUVIER, a BUCKLAND, or an AGASSIZ, to whom, in a visionary mood, we may assign local attributes of personification, and whom we may array in the costume of the carboniferous epoch, so well indicated by the fossil relics of Burdiehouse. She may be armed, *cap-a-pée*, with a resplendent coat of mail wrought from the hard and enamelled scales of the *Megalichthys*; crowned with a wreath of ferns, in which many fantastic species of the *Sphenopteris* are entwined; while in her grasp may be placed a magic wand, wrought from a jointed stem of the

Calamites, at the waving of which, countless bones of fish, including the dazzling scales, the elongated bony rays, and the cranial fragments of vast finny tyrants, burst from their marble prisonhouse amidst a classical shower of coprolitic relics. We may next suppose, that, in obedience to another fiat, various bones reunite and distribute themselves into their respective genera, species, and varieties; the mind being lost in the grotesque appearance of larger monsters, developed in their mixed ichthyoid and sauroid character.

If it be occasionally allowable, in a disquisition dedicated to Philosophy and Truth, to let the imagination for an instant run wild, Truth would at least stipulate that it be strongly pervaded with a philosophical moral. The Genius of Fossil Zoology may therefore rise again to our fancy;—she may point to contiguous limekilns, whence issue dense clouds of vapour; she may demand, with scowling looks, why to these destructive fires, which have blazed for half a century, countless bones have been devoted; and why cremations, in honour of her destructive opponent CYBELE, have so long been rendered; or why no attempt has been made to extricate the treasury of osseous relics enclosed by them, which may have even aided in the composition of the very mortar with which the walls of Edina's geological museums have been cemented.

I will not, in my own defence, venture upon the task of inquiry, Why the limestone of Burdiehouse, situated so near the city of Edinburgh, had not been before examined? or why, in reference to my own private repose, so long as I remained in Edinburgh, I had thought it necessary to exclude Scottish rocks from my researches?

I have not, however, on this account, been the less industrious, although labouring under the inconvenient necessity, either of limiting the object of my tours to the elucidation of the archæology of Scotland, or of selecting any country as a field for geological exertion except that in which I had long resided, and to which I have been long attached by many ties of near connexion and friendship.

Many years had consequently elapsed since my retirement from the study of Scottish rocks, nor did I think that I should ever re-enter that rich, yet almost forbidden, field of Geological observation, however much I valued its high interest. This reluctance was at length overcome by a visit, purely accidental, which I paid on my return from an excursion to Roslin to the limestone quarry of BURDIEHOUSE. My impression upon the first sight of this quarry, to which the individuals who accompanied me will remember I gave utterance, was, that I had found a geological deposit which I had never seen before, but which I had long hoped to discover. It was a freshwater formation belonging to the carboniferous group of rocks.

The result attributable to this occurrence has not, I trust, been overrated.

Upon the occasion of the meeting of the British Association of Science at Edinburgh, the osseous relics in the possession of the Royal Society were submitted to M. AGASSIZ, who considered them as forming some of the most valuable acquisitions

which had ever been made in Fossil Ichthyology, and, in conjunction with Dr BUCKLAND, a request was made to the Council of the Royal Society, to continue their important exertions in preventing the dispersion of the fossil treasures of Burdiehouse.

The following letter, addressed by M. AGASSIZ to Dr BUCKLAND, I beg leave to subjoin:—

“MON CHER MONSIEUR BUCKLAND,—Vos relations avec les membres de la Société Royale, vous permettent mieux qu’à moi de faire une démarche que je crois très-importante. La découverte d’animaux vertébrés dans les carrières de Burdiehouse, a suscité des discussions du plus grand intérêt sur les caractères des êtres de cette époque antique. Ce serait une nouvelle ère pour la paléontologie, s’il pourrait être démontré, comme je le crois, que les poissons de cet âge réunissent à leur organisation particulière les caractères des reptiles d’une classe d’animaux qui n’apparaissent que plus tard en grand nombre. Il faudrait donc poursuivre avec ardeur les fouilles dans ces carrières, et prendre les mesures les plus sûres pour empêcher la dispersion des échantillons, et conserver à la science des documens qui pourront constater une découverte aussi importante.

“Si vous pourriez contribuer à faire prendre ces précautions, vous auriez rendu un grand service aux recherches sur les fossiles.

“Agréez l’assurance de ma considération très-distinguée, et recevez à l’avance mes remerciemens pour tout ce que vous voudrez bien faire dans cette circonstance. Votre tout dévoué,

L. AGASSIZ.”

“EDINBOURG, le 15 Sep. 1834.”

PART II.

THE GEOLOGICAL RELATIONS OF THE FRESHWATER LIMESTONE OF BURDIEHOUSE.

INTRODUCTION.

HAVING in PART FIRST confined myself to the description of the limestone of Burdiehouse, considered as an individual bed belonging to the carboniferous group, I shall now point out its geological relations to other strata, both of an older and newer date.

The carboniferous strata, of which the limestone of Burdiehouse forms a very subordinate bed, appear in the great Lowland valley of Scotland, which is watered by the Tay, the Forth, and the Clyde. Some of these strata, particularly such as are in contiguity with the limestone of Burdiehouse, I propose to consider very generally; first, in regard to their fractures, and, secondly, in regard to the remarkable alternations which they exhibit; and after these considerations, some important inferences may be drawn concerning the geological relations of the freshwater bed, which forms the proper subject of this memoir.

NOTES TO THE INTRODUCTION.

Preparatory to entering upon any investigation of carboniferous strata, a few remarks on the older rocks to which the coal-fields of the south of Scotland have succeeded, may perhaps aid the inquiry. These I shall throw into the form of a note.

No rocks are perhaps better calculated than those of Scotland to aid the inquiry which has been undertaken by various geologists, with the view of determining the extent of those convulsions of different periods, which have been attended with corresponding changes of level affecting the surface of our planet. Sometimes these changes appear to have been the result of sudden violence, and, at other times, of a gradual process of elevation or depression, carried on perhaps during the whole persistence of a geological age, or system. An early elevation of the Grampian ridge, for instance, appears to date from a period immediately subsequent to the formation of such primary rocks as form the ingredients of the Scottish Alps, namely, talcose schist, or primary clay-slate, mica-slate, gneiss, and their accompanying granites, serpentines, or primary trap.

At the foot of the Grampians, in the geographical line which extends from Stonehaven to Bute, transition strata of grauwacke or argillaceous schist appear in succession, which seem to have been deposited in a southerly direction over a considerable tract of space, though at present concealed beneath newer formations. This continuity I have inferred from the fragments of grauwacke schist, which I have found entangled in such trap-rocks of Angus, of the Lothians, of Ayrshire, or of Berwickshire, as had forced their way through superimposed and newer deposits. In the ridge of hills extending from Berwickshire to Galloway, grauwacke schist is seen to emerge.

The grauwacke schist has, generally speaking, a line of bearing from about S. 60° W. to N. 60° E., and dips to the west at very considerable angles, seldom less than 50° or 60°. It is of a dark grey colour, and is either compact or very finely granular. In some places it is highly laminar, and is successfully quarried for roofing slate. It frequently passes, particularly in its upper beds, into a substance of a very arenaceous and mechanical structure, which may be fairly regarded as a harder sort of sandstone. The colour of the sandstone, or schist, thus induced, is more inclined to a light grey, greenish-grey, or yellowish-brown colour than to one of red; though to this rule I have seen exceptions. It is also remarkable for the quantity of mica which it contains. In Ayrshire, beds of granular limestone alternate with the grauwacke schist.

That these beds of grauwacke schist will be found to contain organic remains, particularly in their upper strata, I have strong reason to suspect.

Subsequently to this formation of transition strata, the range of the Grampians appears to have undergone a sudden elevation, which may explain the presence of such lower beds of coarse conglomerate strata as were deposited at the foot of this chain of mountains. I also suspect that about the same period commenced another elevation of the ridge of grauwacke schist which extends from Berwickshire to the Mull of Galloway. But if this southerly elevation may be supposed to have actually commenced about the same period, I conceive that it was under circumstances of far less violence, and that it was a gradual, rather than a sudden process.

But whatever may be the exact nature of these disturbances or convulsions, it is certain that, from the cessation of the grauwacke deposit may be dated the incipient conversion of the considerable track intervening between the chain of the Grampians and the lowland confines, into a sort of basin, which, in the first instance, would no doubt have its continuity much broken by irregularities of surface. This I infer from various insulated and very limited deposits, which appear to me to have a date of formation intermediate to grauwacke schist, and to carboniferous strata. The remark, however, fails in applying to the district north of the Tay, where a continuous depression appears to have been formed, within which was deposited very considerable beds.

The oldest beds which have succeeded to the grauwacke schist, and which repose upon it in an unconformable position, consist of the hard, yet fissile and micaceous sandstone north of the Tay, known under the name of the Arbroath Pave-

ment, which, in its upper beds more particularly, passes into sandstone, often very red, but sometimes of a paler reddish-brown or buff colour, and identifies itself with the old red sandstone of geologists. It is now ascertained that the remains of fish are enclosed in this very early formation of sandstone, and I have also observed in it indications of plants.

The termination of this deposit carries us to the dawn of the era when the carboniferous group of rocks was deposited, preparatory to which I shall make some few remarks connected with the formation of the great lowland basin.

Although I believe that the chain of the Grampians dates, at least, two of its elevations from periods antecedent to the deposit of such strata as are known by the name of the Arbroath Pavement, yet I must consider that its greatest elevation took place immediately before the deposit of the carboniferous group of rocks. That this convulsion was a sudden one, and attended by circumstances of great violence, is evinced by the immense mass of conglomerate strata, which, in being deposited at the foot of the Grampians, repose upon prior formations of the Arbroath pavement, and other analogous strata. It would also appear, that the whole district intermediate to the Grampians and the Tay, and extending SW. by W. to Bute, had likewise been subjected to a similar process of elevation, though under an agency of far less suddenness or violence than that which had thrown up the Grampian chain.

Along with this disturbance, a sort of nearly parallel movement appears to have taken place in the elevated ridge of grauwacke schist extending in a direction of ENE to WSW. from St Abb's Head to Ayrshire and Galloway, which upon this occasion received its great elevation.

Owing to these convulsions, the great chain of the Grampians was elevated considerably above the level of the ocean, as may be shewn by the relative differences of height which appear among the primary strata of the Scottish Highlands, and such limestones of marine origin as may be found in the great valley of the Lowlands. In comparing these levels, and even in allowing for any sources of error arising from comparatively late disturbances of strata, no inference can possibly arise, but that at the time when the coal-measures began to be formed, the Grampians must have sustained a very considerable elevation above the level of the ocean which then subsisted.

The same remark, though in a less degree, applies to the ridge of grauwacke schist which extends from St Abb's Head to Ayrshire, and which towers greatly above the carboniferous strata which repose at the foot of this lofty chain, although it is, at the same time, of much less elevation than the Grampian Alps.

It would thus appear that, intermediate to the Grampian chain, and to the chain of hills, which on the south, bounds the present Lowland valley, a deep basin must have subsisted.

Within this basin the carboniferous strata of the south of Scotland were deposited.

SECTION I.—THE FRACTURED STATE OF THE STRATA IN THE VICINITY
OF THE LIMESTONE OF BURDIEHOUSE.

The strata with which the limestone of Burdiehouse are more or less connected form the great Mid-Lothian coal-district, of which the neighbourhood of Dalkeith may be considered as the centre.

Mr DE LA BECHE, in his excellent little system of theoretical Geology, has remarked of the Earth's crust, that there is scarcely an area of eight or ten miles which has not been more or less fractured; which remark cannot be better illustrated than in the Scottish coal-fields, which may be considered as exhibiting a congeries of fractured areas, separated from each other by long lines of fissure.

The rationale of this fractured state is now beginning to be understood, for which we are indebted to an eminent geologist, M. DE BEAUMONT.

The theory hinges upon the following circumstances:—The interior of our globe has had its temperature diminished sensibly by the reduction of heat, and it has consequently contracted. The earth's crust, however, has preserved, at the same time, a nearly rigorous constancy of temperature, its refrigeration having been almost insensible, and hence little contraction has ensued. Keeping, then, in view these inequalities of contraction, it would follow that, as the interior of the globe must, in length of time, have had its temperature lowered far more than its exterior crust, its capacity must have undergone a proportional excess of diminution. In this case, the external solid crust, in striving to conform itself to the fluid or viscid surface beneath, and to embrace it more closely, would undergo considerable dislocations;—and, from a cause so generally operating, fractures would be induced, which would have a greater or less tendency to a parallel direction.

In the Mid-Lothian coal district decided lines of fracture from these causes must have very early taken place. They have, for

the most part, a direction between the limits of SS.W. to NN.E., and S. W. to N. E. ; and, in this respect, remarkably confirm the theory of M. DE BEAUMONT.

The first line of fracture may be traced from the vicinity of Burdiehouse, and not far from the trap of the Pentlands, in a direction from SS.W. to NN.E. as far as Joppa on the Frith of Forth. This line of fissure passes to the west of, and close to, the limestone of Burdiehouse.

A second line of fracture nearly follows the line of the North Esk, from the vicinity of Penicuik to Bilston Burn near Loanhead, whence it is continued to the west of Musselburgh, in a direction from S.W. by S. to N.E. by N. This great line of fissure was first traced by WILLIAMS, the mineral surveyor, who has written so ably on the coal-fields of Scotland.

A third line of fracture appears to nearly follow the course of the South Esk, where it may be traced at intervals from the vicinity of Dalhousie to the east of Musselburgh, in a direction from SS.W. to NN.E. This line of fissure is not so evident, owing to the comparatively little difference of inclination subsisting among the strata upon each side of it, as well as the covered state of the ground.

A fourth line of fracture, owing to the covered state of the ground, is not easily traced. It probably has its rise from the vicinity of the Moorfoot Hills. Its course is assuredly along the Roman mount, east of Dalkeith, where it is possibly implicated with an intrusion of trap, which may have not found its way to the surface. The direction of the fissure is not far from SS.W. to NN.E.

There are, however, other fissures varying from these, which do not appear to be of any great extent. Among these, I do not include the numerous subordinate faults or troubles which are so well known to miners. One near Dalkeith, perhaps larger than common, is said to run in a transverse direction, nearly from N. W. to S. E.

Fractures among the coal strata, more or less inclined to parallelism, having been thus induced, a subsequent effect produced by the struggle of disjointed portions of the earth's surface to conform themselves to the diminished capacity of the internal nucleus of the globe, would be manifested in the edges of these fractures being pressed forcibly against each other, by which some of the strata bounding the edge of a line of fracture would give way to this mutual compression, and would consequently be thrust upwards in the form of mountain ridges.

Accordingly, these mountain ridges observe lines of direction which are often parallel, or nearly so, to lines of fracture.

It has been thus shewn, that the Mid-Lothian coal-district exhibits lines of fracture nearly parallel to each other ;—that causes in operation had a tendency to force these broken surfaces into a nearer contact with the centre of the earth, in order to adapt themselves to the diminished capacity of the nucleus of the globe ; that these causes had induced the edges of these fractures to approximate to each other ; and that in the mutual force and struggle thus used, such edges of fractures as during the struggle had given way, were thrust up into mountain ridges.

It must also be evident, that in the case of any newer contracted state of the nucleus of the globe, inviting a fresh struggle of its broken crust to adapt itself to an internal surface of less capacity, old lines of fracture would of course be the lines of least resistance. And hence, broken up and tilted masses would continue to be thrust up in the same line of direction.

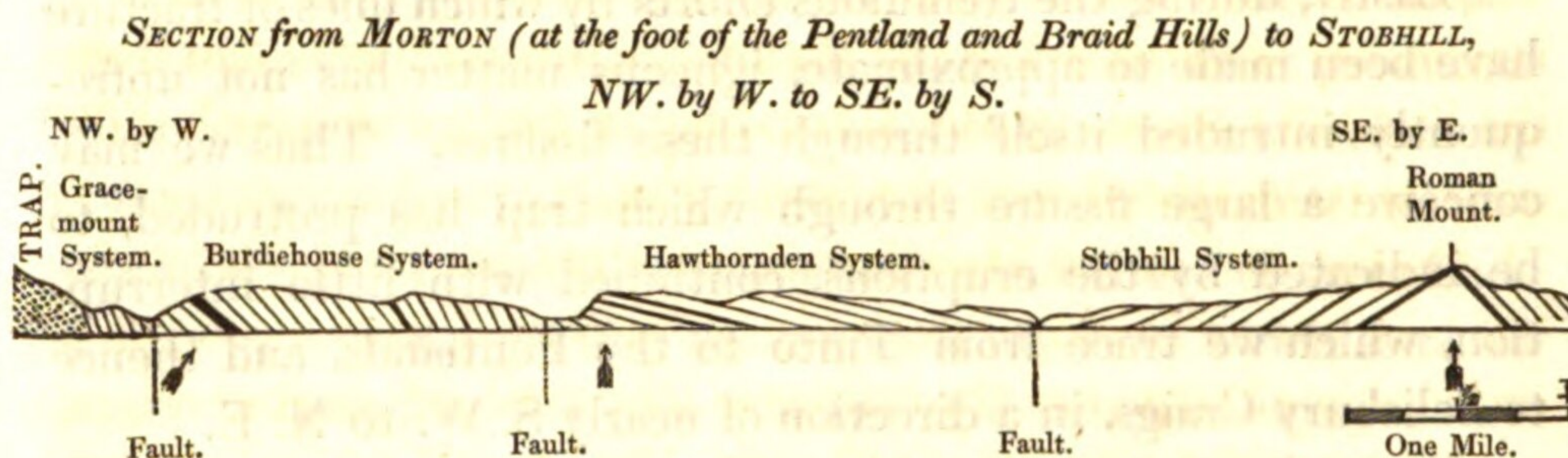
These efforts of a subsequent date appear to have been gradual, and even oscillatory, as will be explained hereafter. Consequently, few or none of the fractured systems of strata which I have described, shew at their lines of fault marks of sudden violence ;—a circumstance which had been previously observed by WILLIAMS, in the instance of the great fault which divides the Hawthornden and Burdiehouse systems. In short, every thing indicates, that these later movements must have taken place by very slow, prolonged, and tranquil processes.

Lastly, during the tremulous efforts by which lines of fracture have been made to approximate, igneous matter has not unfrequently intruded itself through these fissures. Thus we may conceive a large fissure through which trap has protruded, to be indicated by the eruptions, continued with little interruption, which we trace from Tinto to the Pentlands, and thence to Salisbury Craigs, in a direction of nearly S. W. to N. E.

From these observations it would appear, that the carboniferous strata under our consideration shew striking marks of the upheavings and the rents which they have undergone both before and subsequent to the completion of their deposit, accompanied with eruptions through them of plutonic rocks. In consequence of these rents, and of the uplifting power which has been exerted along the line of them, the coal-fields of Mid-Lothian have been broken up into various systems of strata, severally differing from each other in the extent of the beds which have been made to emerge. This difference would naturally be in conformity with the circumstances under which the uplifting force has exerted its influence.

In examples where the anticlinal energy has acted powerfully at one and the same time upon a great extent of surface, we find that at the line of rent or fissure very deep-seated beds have been made to emerge, or crop out:—as may be shewn on the coast of North Berwick and among the Pentlands, by the emergence of beds even inferior to the carboniferous group. But examples are far more numerous of the line of fracture being distinguished by the cropping out of no deeper seated beds than those of a marine limestone, to which I have given a middle place in the carboniferous system to which the limestone of Burdiehouse belongs.

The systems of strata, separated from each other by lines of fissure which are in greater or less contiguity with the limestone of Burdiehouse, I shall now explain in reference to the following section.



In reference to this section, it will appear that I have distinguished four systems of strata, divided from each other by lines of fissure, viz. the Gracemount, the Burdiehouse, the Hawthornden, and the Stobhill systems.

In giving a very brief explanation of these various systems, I shall commence with the Hawthornden system, notwithstanding the greater degree of obscurity which still hangs over it, in reference to the question, long since agitated, regarding its geological position.

The Hawthornden system comprises a peculiar thick bed of reddish and softish sandstone, in which small rounded pebbles of quartz are inclosed. It is geologically known by the name of the Roslin sandstone. This sandstone, which, from its quartzose ingredients and other circumstances, appears to me to have been deposited soon after the formation of transition rocks, may have undergone an earlier elevation than perhaps any other strata belonging to the systems which are laid down. The consequence of this priority of elevation may have been that want of continuity which the coal strata superimposed upon the Roslin sandstone exhibit, in relation to other coal seams lying to the west and east of them; although, from a mineralogical correspondence, their relative date may perhaps be correctly estimated. The thick bed of Roslin sandstone, which is surmounted by eight or more conformable seams of coal, exhibits a very trifling dip of 10° or 12° to the east or north-east. It is separated from the highly inclined strata of the Loanhead coal-measure, belonging

to the Burdiehouse system, by the second line of fault described, which may be observed in the channel of Bilston Burn ; and from the Stobhill system, by the third line of fault which with difficulty is to be traced near the South Esk.

On the east of the Hawthornden system, occurs that of Stobhill. A line of fracture, probably accompanied with a concealed protrusion of trap, has thrown up a limestone of marine origin, which forms the ridge of the Roman Mount, and from this anticlinal centre, superincumbent strata of sandstone, shale, and coal, dip towards the surrounding low declivities. The system of Stobhill has a westerly dip, amounting in some places to 30° . It is continuous with the coal-measure of Brians, which enumerates twenty seams of coal or more.

To the west of the Hawthornden system, may be observed the most complete suite of carboniferous strata of which Mid-Lothian has to boast ; namely, the conjoint systems of Gracemount and Burdiehouse.

Immediately to the east of the Pentland trap, beds of sandstone are to be found, which I have named the Gracemount system, from a quarry recently opened there, where the strata in their nearly vertical position may be observed. They belong, as I conceive, to deeper seated beds, which have been thrown up during an early eruption of the Pentlands. They are separated from the Burdiehouse system by the first line of fault enumerated.

The Burdiehouse system comprises a series of sandstones, shales, limestones, and coal, among which the Burdiehouse limestone appears in a very inferior position. The system is separated from that of Gracemount by the first line of fault described. Near this line of fissure the strata of the Burdiehouse system dip to the south-east at about 23° to 25° ; but, as we approach towards the Hawthornden system, the dip may be found to gradually increase, until it attains, near the second described line of fault observable at Bilston Burn, so great a dip as 56° , or even more. It is difficult to explain this circumstance without taking

into account, that this increased dip might have been caused by some renewed, yet very slow elevation of the Hawthornden system of strata, by which a sort of lateral pressure had been induced among the contiguous strata of the Burdiehouse system, sufficient to increase their inclination from 23° to 56° or more.

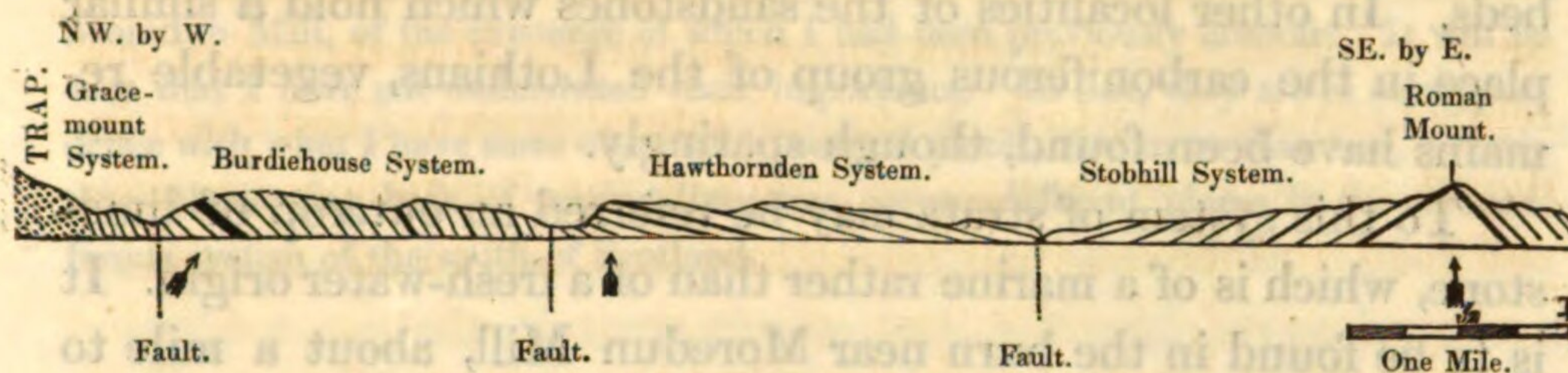
Having at length briefly described the systems of strata to be found in the great coal-field of Mid-Lothian, as indicated by fractured areas, I shall now confine my attention to the connected ones of Gracemount and Burdiehouse.

SECTION III.—THE GRACEMOUNT SYSTEM OF STRATA.

Before describing the beds to which the limestone of Burdiehouse belongs, it will be necessary to previously notice the strata lying to the west of, and separated from, the Burdiehouse system by a line of fissure. The Gracemount system occupies a place intermediate to this fault and the trap of the Pentlands.

A sandstone, which perhaps holds the lowest place in the carboniferous system of the great Lowland valley of Scotland, is composed of fine, yet very uncrystalline, grains of siliceous matter; it contains little mica; it is of a deep red colour, owing to the iron which is diffused through it; and it is of a soft consistence. This, the most deep-seated bed, rises to day in a few places only, and, if it is to be traced in the group of strata to the west of the limestone of Burdiehouse, we must perhaps look for it among the upheavings which occur in the immediate vicinity of the range of trap rocks, extending from the chain of the Pentlands, with some little interruption, to Arthur's Seat. Most probably this sandstone may be proved to be wholly, or in part, of marine origin,—a suspicion which I have formed upon certain organic remains apparently referable to this deposit.

But quitting the consideration of a sandstone, the existence of which in the Gracemount system is at best dubious, owing to the rocks being here much concealed, I shall proceed with a description of what is actually known.



To the west of the line of fracture described, strata of sandstone are thrown into a vertical position, or nearly so, as was shewn in an old quarry adjoining the village of Burdiehouse, which is now filled up. But similar phenomena may be still observed within the park of Gracemount, where the same continuous strata, consisting of a pale, yellow-coloured micaceous sandstone, with a direction from S. 10° E. to N. 10° W., are inclined to the south-east, at so great an angle as 80° . These strata appear to have been the tilted beds which had been thrown on edge during one of the convulsive movements connected with the evolution of the trap of the Pentlands, to which range of hills they are contiguous.

The limestone of Burdiehouse, however, which is situated to the east of these nearly vertical beds, dips no more than from 23° to 35° to the south-east, and shews in other circumstances that it was thrown up by an anticlinal force distinct from that by which the strata to the west of it appear to have been tilted, though originating doubtless from the same general cause.

The nearly vertical sandstone of Gracemount forms a good freestone. It is of a light yellowish colour, and it contains mica as an ingredient. In the less inclined sandstone of Craigmillar, which is apparently a continuation of the Gracemount bed, and which shews many variations of colour, as light yellowish, grey, or even pale red, some of the strata enclose very small attrited portions of quartz, as well as of a substance, which, from its mixed siliceous and argillaceous character, and from its grey, or bluish-grey colour, may be considered as the detritus of older grauwacke

beds. In other localities of the sandstones which hold a similar place in the carboniferous group of the Lothians, vegetable remains have been found, though sparingly.

To this system of strata may be referred an outcrop of limestone, which is of a marine rather than of a fresh-water origin. It is to be found in the burn near Moredun Mill, about a mile to the north of Burdiehouse. A bed not many feet in thickness, and containing producti, encrinites, &c. is alternated with shale; but I suspect that more than one bed may be found to thus alternate. This limestone and the strata associated with it dip variously, and shew marks of disturbance. The inclination is to the south-east, at angles varying from 44° to 50° , and in some places it is even greater.

This limestone of marine origin is cut off, by the great fault described, from the strata connected with the Burdiehouse limestone, and hence their exact relative position cannot be well ascertained. But I am of opinion that the epoch at which the Burdiehouse and the Moredun Mill limestones were severally formed, cannot be widely different.

The limestone of Moredun Mill is interesting in this respect,—as shewing that a contiguous and shallow sea had subsisted about the time when the Burdiehouse limestone was deposited.

A similar knowledge I have also acquired from studying the strata near New Cumnock in Ayrshire, where there is a very deep-seated bed of marine limestone, which, when compared with another similar limestone much higher up in the series of carboniferous beds, holds the same relative place as that of Burdiehouse; and, when compared with the Moredun Mill limestone, maintains the same deep seated position, in reference to a far higher and newer marine limestone, which is that of Gilmerton.

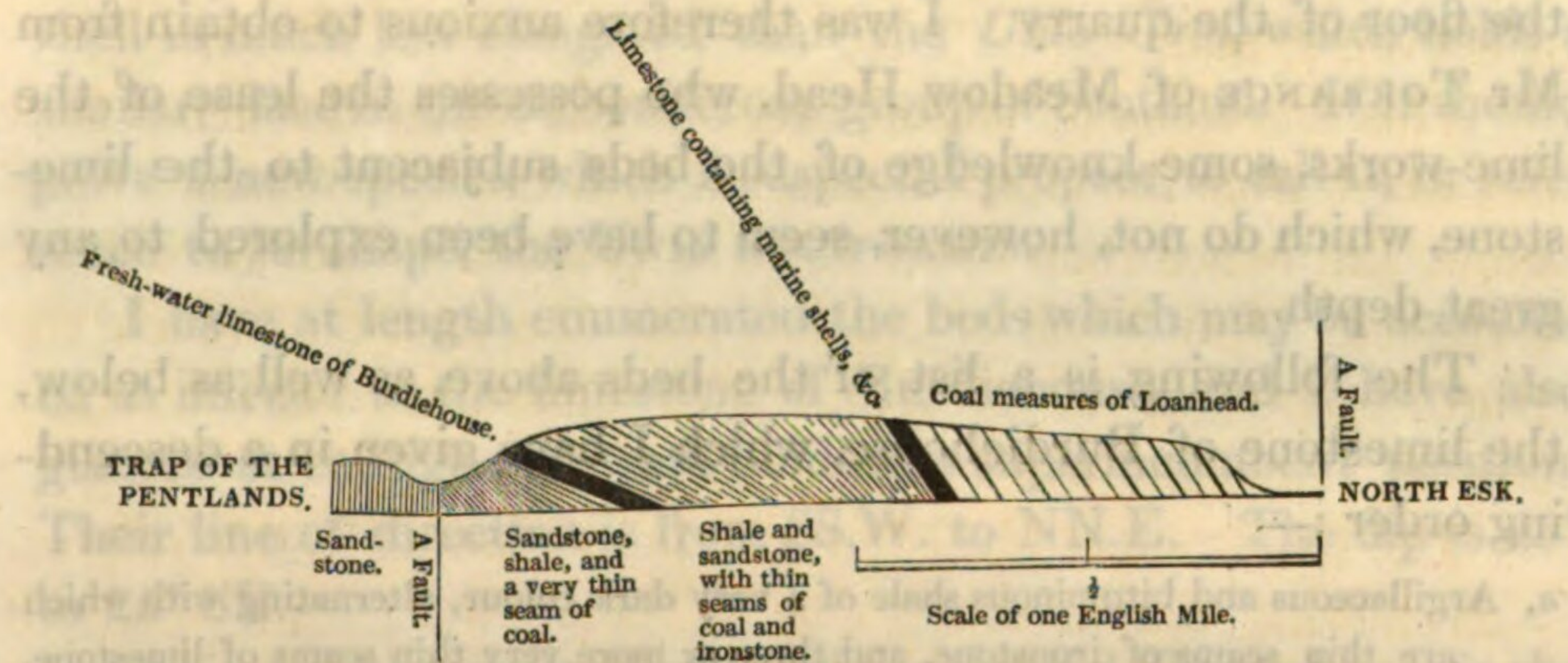
NOTES TO SECTION III.

I have to thank Mr CHARLES MACLAREN of Edinburgh, who is well known for the sensible descriptions which he has at various times given, in the Journal which he conducts, of the geology of Edinburgh, as well as for the perspicuous and popular

style in which they are written, for calling my attention to the seams of limestone at Moredun Mill, of the existence of which I had been previously unaware. It will be seen that I have not under-rated their importance. In fact, they are in correspondence with what I have since observed in several places, that more than two, or even three alternating beds of marine limestone occupy different places in the carboniferous system of the south of Scotland.

SECTION IV.—THE BURDIEHOUSE SYSTEM OF STRATA.

The system of strata connected with the limestone of Burdiehouse, is to the east of the great fault described in the last section, which has brought to view deep-seated beds.



I may now remark, that, in reference to the section given, I shall point out, in their several orders, first, the strata in immediate association with the limestone of Burdiehouse; secondly, the description of overlying beds contained between the Burdiehouse limestone and the limestone of Fountain-well, which is the name given to the site of a cluster of houses close to the village of Loanhead; thirdly, the character of the Fountain-well limestone, which appears to differ from that of Burdiehouse, in containing marine remains; and, fourthly, the rich coal-measures of Loanhead which take the highest place in the system.

SECTION V.—THE STRATA IN IMMEDIATE ASSOCIATION WITH THE LIMESTONE OF BURDIEHOUSE.

To the sandstone of the Gracemount system, I consider the limestone of Burdiehouse, and its associated beds of argillaceous shale, as having immediately succeeded. I need scarcely recapitulate its character, but merely remark, that no confirmed marine remains have, to my knowledge, ever been found in it ;—that it contains the plants usually found in coal-fields in a most remarkable abundance, as well as numerous Entomostraca, together with the relics of fish, large sauroid bones, and coprolites, and that I consider this limestone as of fresh-water origin.

No rock beneath this bed is developed, except that which forms the floor of the quarry. I was therefore anxious to obtain from Mr TORRANCE of Meadow Head, who possesses the lease of the lime-works, some knowledge of the beds subjacent to the limestone, which do not, however, seem to have been explored to any great depth.

The following is a list of the beds above, as well as below, the limestone of Burdiehouse, which I have given in a descending order :—

- a, Argillaceous and bituminous shale of a very dark colour, alternating with which are thin seams of ironstone, and three or more very thin seams of limestone, the latter being from 2 to 2½ inches thick, and at intervals from each other of 27 to 36 inches. From 30 to 50 feet of shale are exposed.
- b, The limestone of Burdiehouse, 27 feet thick.
- c, A pavement of rather soft blaes, 2 to 3 feet thick. This is an argillaceous and bituminous shale mixed with calcareous matter, and forming, near the junction of the rock, or immediately subjacent to it, an impure limestone.
- d, Limestone of inferior quality, 3 or 4 feet thick.
- e, Black blaes (argillaceous and bituminous shale), rather soft ; 3 or 4 feet thick.
- f, A seam of coal 6 to 10 inches thick.
- g, “ Yellow clay ;” (an argillaceous and shaly sandstone ?) Some of the workmen describe this bed as *metal*, and as forming a very coarse freestone. Depth unknown.

The beds of argillaceous shale, both above and below, enclose the same organic remains as are found in the limestone of

Burdiehouse, along with coprolites, shewing that they are themselves a portion of the lacustrine deposit of this locality.

In the uppermost bed of argillaceous shale, specimens of the *Unio* have lately been discovered by the quarrymen, which were placed in my hands by Mr ROBISON.

In the annexed wood-cut, the natural size of the bivalve is represented, though some specimens occur a little larger. It



does not appear to me that this species has yet been described. It differs from any *unio* which I have yet seen represented in the tumidity of its form, which is rounded into a sort of nut-shape. The shell is much less elongated than the *Unio Urei*, which holds a similar place in the carboniferous group of Scotland. If it should prove a new species, which I suspect, I propose to call it, in reference to its shape, the *UNIO NUCIFORMIS*.

I have at length enumerated the beds which may be accounted as inferior to the limestone of Burdiehouse, and I have also glanced at contiguous strata holding a superincumbent position. Their line of direction is from S.S.W. to N.N.E. The dip is 23° to 25° SE.

Owing to the covered state of the ground, Burdiehouse is the only locality where this limestone is seen to crop out. The prevailing notion is, that it reappears at the foot of the Pentlands, and that, at Carlops, it is to be identified with a seam of limestone not more than six inches thick. But this is a very doubtful opinion.

Another circumstance to be remarked is, that there is no evidence of the deposit being a continuous one. Thus, in the excellent manifestation of strata which may be traced from the vicinity of Siccar Point in Berwickshire to Cove, this fresh-water limestone is deficient. But, in the place of it, there appears to be a bed of bituminous shale, in which I detected the characteristic fern of Burdiehouse, the *Sphænopteris affinis*, along with coprolites, and

the remains of smaller fish. And, on examining the outcrops of strata in other localities, this deposit was equally wanting.

Some other fresh-water limestones will be described in the supplement to this memoir. In the mean time, I shall remark, that they appear to me, like the limestone of Burdiehouse, mere local deposits of calcareous matter.

SECTION VI.—THE STRATA INTERMEDIATE TO THE LIMESTONE OF
BURDIEHOUSE AND THAT OF FOUNTAIN-WELL.

The interval of space between the limestone of Burdiehouse and that of Fountain-well, near Loanhead, comprises alternations of sandstone, and argillaceous and bituminous shale, in which are ironstone bands, and thin and unworkable seams of coal, with the exception of one bed of coal, named the North Green seam, which lies immediately below the Fountain-well limestone. At the same time, although all the strata rest conformably upon each other, we find that their angle of inclination has gradually increased. At Burdiehouse, the limestone dips from 23° to 25° to the south-east; but, as we approach a higher series of beds, the dip is 30° or 40° , and upwards.

NOTES TO SECTION VI.

As it is of great importance that no doubts should subsist regarding the geological position which I have assigned to the limestone of Burdiehouse in the carboniferous system of strata, the details will be given at length.

It has been shewn that, immediately above the limestone of Burdiehouse, which is of the thickness of 27 feet, occur beds of argillaceous shale, through which bituminous matter appears to be diffused. These strata are visible, from the operation of quarrying, to the height perhaps of 30 to 50 feet, or even more. Alternating with these beds of shale are three, or even more, seams of a ferruginous limestone, severally from 2 to $2\frac{1}{4}$ inches thick, and occurring at intervals from each other of from 27 to 36 inches.

With respect to strata still higher, and next in succession, I was enabled to obtain some little knowledge of them, in consequence of a shaft which had been sunk with the view of carrying off the water from a freestone quarry, situated at no great distance, near the village of Straton. The distance between this freestone and the shale, was described to me as about fifty fathoms in perpendicular depth, in which nothing was found but *Dalk*; that is, a soft argillaceous and bituminous shale. But this description I must a little qualify. I observed, from the fragments thrown out,

that a stratum had been pierced, consisting of small water-worn pebbles of quartz, cemented by a soft greenish and yellowish argillaceous substance, apparently decomposed trap or felspar. The argillaceous substance of the conglomerate rock appeared to me indicative of some igneous eruption, though perhaps remotely situated, which must have taken place not long after the deposit of the Burdiehouse limestone.

The sandstone of Straton quarry is of a yellowish, or yellowish-brown colour, and of a hardness which recommends it as a durable freestone. It dips rather confusedly, varying from 14° to 30° east by south, south-east, or even south-east by south. Above it are beds of shale. It is evident that great disturbances have here taken place, which are further manifested as we approach the highroad leading to Loanhead, where the sandstone which is exposed betrays much irregularity of position. Its general angle of inclination is about 22° , or upwards, to the south-east. It is surmounted by bituminous shale.

Between Straton quarry and Fountain-well, near Loanhead, a distance of about five furlongs, we continue our section at right angles to the line of direction observed by the strata. With the exception of two or three spots of ground, where I found beds of slaty sandstone or of shale crop out, the ground is much covered. But my knowledge of this interval of distance was rendered perfectly satisfactory by the information communicated to me by Mr Ross of Loanhead, the intelligent greave of Sir George Clerk of Penicuik, Bart. Mr Ross has made himself well acquainted with the different strata of his neighbourhood; and from him I acquired the knowledge, that the covered ground between Straton and Fountain-well had been very carefully explored, in the endeavour to find out if there were any outcrops of coal. The result of the examination was, that the interval of space between Straton quarry and Fountain-well, near Loanhead, consisted of alternations of freestone and coal blaes, (sandstone and bituminous shale,) with ironstone bands, which also contained very thin and unworkable seams of coal. From this remark, however, I except a thicker seam of coal, which is said to lie immediately below the Fountain-well limestone.

As far as the few visible outcrops of this space of ground enabled me to judge, I was led to infer that the dip of the strata, in ascending from the lower to the higher beds, was gradually increasing. For instance, the deep-seated bed of the Burdiehouse limestone inclines from 23° to 25° to the south-east; but, in the strata higher up in the system, the inclination had increased to not less than 30° or 40° , or even more.

The highest bed of the series of strata, intermediate to the limestone of Burdiehouse and the limestone of Fountain-well, is the seam of coal formerly alluded to, known by the name of the "North-green seam." It is of the thickness of $4\frac{1}{2}$ feet; but, having been very early wrought out, its outcrop is no longer visible. It is affirmed to lie immediately below the limestone of Fountain-well.

A bed of coal holding this position is not unknown in other vicinities. Mr WILLIAMS has remarked a seam which occurs in this position, near to the foot of the Pentlands, and I have myself observed another similar one in the vicinity of Clerkington.

SECTION VII.—THE LIMESTONE OF MARINE ORIGIN AT FOUNTAINWELL,
NEAR LOANHEAD.

The limestone of Fountain-well, which occupies a sort of middle place in the system, forms a portion of the continuous bed, which may be traced, cropping out at various sites, in a line, extending from the neighbourhood of Joppa to Gilmerton, and thence to Fountain-well; a distance of three miles. It is in general very impure, being much mixed with siliceous matter, whence its great hardness, which, in the absence of whinstone or trap, has caused it to be used for repairing the highways. At Gilmerton some portion of it is so much mixed up with argillaceous matter as to pass into common shale.

This limestone, in its impure state, is named *Limestone Blaes*. But it contains *fakes*, or seams, of very pure limestone, which at Gilmerton are wrought for the kiln to the thickness of 14 feet. The bed at Fountain-well encloses three *fakes*, or seams, each about two feet thick, or $6\frac{1}{2}$ feet conjointly.

The whole of the limestone, whether pure or impure, is of a blue, or bluish grey, colour.

To farther distinctions I shall allude when I have to compare this limestone with that of Burdiehouse. In the mean time, I shall remark, that it contains marine remains, such as encrinites, corallines, producti, &c., which are severally absent in the Burdiehouse limestone.

At Fountain-well, the circumstance most worthy of remark at present, is the further increase of dip which has taken place in the tilted and upper beds of the system under examination. In the inferior bed of Burdiehouse, the dip was 23° to 25° to the south-east; but in the much higher limestone of Fountain-well, it has increased to 50° or 52° south-east.

SECTION VIII.—THE UPPER SERIES OF SANDSTONES, SHALES, AND RICH SEAMS
OF COAL, FORMING THE LOANHEAD COAL-MEASURES.

I shall, lastly, describe the strata superjacent to the Fountain-well limestone.

Immediately above this limestone is another seam of coal, named "*The North Coal*," which, like the North-green seam, is $4\frac{1}{2}$ feet thick. With this seam all marine remains disappear, and we arrive at the coal strata of Loanhead, which, as the section shews, rise still higher in the system.

The coal strata of Loanhead consist of alternating beds of sandstone, argillaceous and bituminous shale, containing iron-stone bands, coal, and some little limestone. The workable beds of coal are to the number of twenty-five. They are from 2 to 10 feet in thickness.

In these beds, the angle of inclination is still upon the increase. I found, upon descending into the mine of Loanhead, that the seam named the Stair-head coal, had a dip of 56° to the south-east. But it is affirmed, that, among some of the strata, the inclination is still greater. From these circumstances, the beds have acquired the name of *Edge seams*, in contradistinction to the more horizontal strata lying to the east of them, belonging to the Hawthornden system, which bear the name of *the Flat seams*. Where the edge and the flat seams appear in contact, which I found to be in the channel of Bilston burn, south of Loanhead, some confusion of the strata ensues, indicative of a great fault, yet unaccompanied with marks of violence.

Among these coal-measures there are at least four slips or dislocations, by which the coal is variously thrown up and down from thirty to sixty fathoms.

A section of the seams of coal, "as they stand in the mines of Brughlee and Mavisbank," was made some years ago. It is not every thing which the geologist could desire, as it does not include the character of the strata intervening between the coal-seams. But this deficiency I have supplied, as well as I was able, from the information which has been given me at the mine, particularly by Mr Ross.

I have also submitted the section to some alteration in its arrangement, in order to shew at one view the overlying character of the strata.

*Section of the Coal Strata of Loanhead, which repose upon the Limestone containing Marine Remains.
In a descending order.*

	Fathoms.	Ells.	Feet.	Inches.		Fathoms.	Ells.	Feet.	Inches.
No proper thickness is given of the sandstone which forms the higher part of the beds. It is stated that from the surface to Mavisbank, where the day level has been made, is 40 fathoms. From the surface to Bilstone mine is estimated at 26½ fathoms.					Stinkie or Peacock,	...	...	5	
					Argillaceous shale, ironstone bands and sandstone,	12	...	...	6
					Coal Rough,	...	...	3	
					Argillaceous shale, ironstone bands and sandstone,	3	...	...	
Wood Coal,	...	...	2		Glass Coal,	...	...	3	6
Sandstone and bituminous shale,	91	...	3		Sandstone,	5	...	...	1
Splint Coal,	...	...	3		Brown Coal,	...	...	2	6
Argillaceous shale, alternated with seams of sandstone, severally 3 or 4 feet thick, and containing about the middle of the space 2 feet of bastard limestone, inclosing calcareous spar,	48	...	...	6	Sandstone,	11	...	2	
					Stonie Coal,	...	...	4	6
Flex Coal,	...	...	5		Sandstone,	2	...	...	
Argillaceous shale and sandstone, containing seams of ironstone and a bastard limestone,	12				Hope's Coal,	...	...	2	
Parrot Coal (also called Rumbles).	...	...	3		Sandstone and shale,	4	...	1	
Argillaceous strata and sandstone, with their seams or forke of coal,	4	...	4		Battie's Coal,	...	...	3	
Great Seam (of coal),	...	...	8		Sandstone and shale,	5	...	1	
Sandstone,	4	...	6		Corbie Craig (coal)	...	...	8	
Stair-Head (coal),	...	...	3	4	Six feet of sandstone resting on a thick mass of argillaceous shale,	20	...	...	6
Sandstone shale, &c.,	12	...	3	6	Andrew's Coal, or Little Splinty Coal,	...	...	4	
Charlie's Coal,	...	...	2		Sandstone and Shale, &c.,	8	...	...	6
Various strata,	4				Little Coal,	...	...	1	6
Moffat's Coal,	...	...	2		Stratum unknown,	...	...	...	6
Various strata,	2				South Coal,	...	...	5	
Gillespie Coal,	...	...	3	4	Sandstone and Shale, &c. . . .	...	...	6	6
A very thick bed of argillaceous shale, which contains ironstone bands. Below it a bed of sandstone, which forms the roof of the Black Chapel coal,	17	...	5		Little Splinty Coal,	...	...	1	6
Black Chapel (coal),	...	...	5		Sandstone and Shale, &c. . . .	1	1	...	
Indurated argillaceous shale and ironstone bands,	...	3	...		North Coal,	...	...	4	6
Perpetual Coal,	...	...	2	2	Beneath the north coal I believe that there is bituminous shale with ironstone bands, and free-stone.				
Sandstone and argillaceous shale,	6	...	3		And below these strata is,				
Kittle Purse Coal.	...	...	3		Limestone, contain-				
Argillaceous shale, ironstone bands, and sandstone,	13	...	3		ing marine remains,				
					Consisting of limestone blaes, or an impure limestone, in which occur three seams of pure limestone.				
					The interval between the North coal and North-Green seam is estimated at	100	...	...	
					North-Green Seam of Coal (at present wrought out), lying beneath the limestone,	...	...	4	6

SECTION IX.—REMARKS ON THE ALTERNATIONS OF BEDS OF FRESHWATER AND MARINE ORIGIN, AS THEY OCCUR IN THE BURDIEHOUSE SYSTEM OF STRATA.

No geological phenomena are more striking than the very miscellaneous beds which succeed each other in the Burdiehouse system of strata. But similar phenomena are frequent in all the coal districts of the south of Scotland.

Some of these alternations of different deposits are explicable in reference to causes which are still operating, although the character of ancient geological agencies far outweighs in magnitude any system of causation which is at present effecting changes on the surface of our planet.

A continued humid state of the atmosphere, for instance, which is inferred to have existed during the carboniferous epoch, would manifest itself in a power of disintegrating previously formed rocks, to an extent of which we have little conception at the present day, as well as with a proportionate degree of acceleration. The very thick mass of sandstone which has enclosed the fossil trees of Craigleith is an instance, not only of the extensive disintegration of pre-existing rocks, but likewise of the very sudden drifts to which the earth, in its ancient state, has been subjected. One of the fossil trees, 24 feet in length, was found inclosed in strata dipping at little more than 10° . The tree, however, had an inclination of 63° ,—very different from that of its nearly horizontal and inclosing beds. This circumstance of inclination shews that the strata could not have been the result of a slow and quiet deposition, otherwise the tree would have decayed long before the uppermost stratum had been deposited. It was doubtless conveyed to its destination by some sudden and considerable drifting from high lands; probably, by the sweeping deluges of rain to which the humid atmosphere of so early a state of the globe would be subject.

Other phenomena, however, in their reference to causes which

are still operating, meet with even a less adequate explanation, unless they may be compared with the tranquil elevations of land which have been long going on in Scandinavia, or with the comparatively trifling oscillations of movement which have been detected on the well known site of the Temple of Jupiter Serapis.

In short, no geological phenomena are more striking than the alternations of fresh water and marine beds which are manifested in strata, such as those which I have described.

The carboniferous strata of the Gracemount and Burdiehouse systems, may be summed up as follows :

The lower beds comprise sandstones of considerable thickness, alternated, as we ascend in the series, with argillaceous or bituminous shale, and with limestones, some of which give indications of a marine, and others of a fresh water origin ; the latter containing remains of plants and fish. Coal begins to be developed in these beds, though sparingly.

In a second, and higher description of beds, the sandstone alternates more frequently with beds of argillaceous and bituminous shale ; the latter containing nodules or bands of ironstone, as well as seams of coal, which, though numerous, are, with few exceptions, thin and unworkable. These higher strata are particularly interesting for the renewed development of a limestone containing marine remains, with which they alternate.

In a third description of beds, which take a still higher place in the carboniferous system, sandstone and argillaceous shale alternate with rich seams of coal, of which about twenty-five have been enumerated.

From this summary it appears, that these alternating beds consist of sandstone, shale, coal, a fresh-water and a marine limestone. Their separate character I shall briefly discuss, previous to investigating the circumstances of their alternation.

Deposits of sandstone, which are the disintegrated materials of previously existing rocks of a siliceous character, have no doubt

been transported into the basins which they have occupied, by the sudden or gradual operation of streams or rivers. Some sandstones, as, for instance, certain beds to the east of Dunbar, contain marine shells, while the majority of other sandstones inclose numerous plants, and thus afford indications rather of lacustrine than of marine deposits.

Argillaceous shale, which, in the limestone quarries of Gilmerton, is filled with marine shells, and at Burdiehouse contains the freshwater unio, represents the mud, or silt, accumulated in the beds of ancient rivers, fresh-water lakes, or seas.

Limestones, as I have urged, may be of two kinds. While that of Gilmerton, adjacent to the Burdiehouse quarry, abounds in corallines, encrinites, and shells, all evidently marine, these are in vain sought for in the other limestone which presents the remains of fish, apparently inhabiting fresh-water, and of ferns, lycopodiaceous plants, and such aquatic vegetables as flourish most among fresh-water lakes and marshes. While the one limestone, therefore, is the memorial of a sea, the other limestone indicates some fresh-water river or lake, within which calcareous matter was elaborated.

With regard to coal, most of the seams of this substance have resulted from the decay of vegetables which have grown upon the very site in which such seams of coal are found. This fact has been incontestibly shewn in the Northumberland coal-field, where the large roots of *Stigmariæ* have been traced in coal or shale, indicative of the vegetable mud in which they grew. It has been therefore inferred, that many of the plants of coal-fields flourished in still and shallow water.—(*See Preface to Vol. II. of the Fossil Flora of Professor LINDLEY and Mr HUTTON.*) Some species of coal, however, it is supposed, might have been brought from a distance in the form of drifted vegetable matter, to which origin certain kinds of cannel, or parrot-coal, are referred. But the absence of all attrited, or water-worn pebbles within the substance of coal, is fatal to this alleged origin.

Such being the plausible origin of carboniferous beds, the next important circumstance to notice is their alternation. And on this question the following considerations are suggested.

A sandstone, of itself, may simply indicate *sand*, which had been transported by natural causes, or familiar terraqueous convulsions ;—it may indicate a quiet transportation of its ingredients to the beds of lakes or seas, and as quiet a deposition. Argillaceous shale, also, may be regarded as a tranquil deposit of silt in some lake, or sea ; while limestone, whether it occurs beneath marine or fresh waters, may be the testimony of some calcareous elaboration through deep fissures incidental to the fractured state of our globe. And, when we find alternations of these deposits, it is possible that we may be presented with no phenomena which are not familiar to us at the present day. The river, for instance, which at one period deposited sand, may, from a change of its course, which frequently happens, be fraught with silt, or clay. Meteoric agencies may interfere, which would bury a deposit under a deep accumulation of distantly transported sand or mud. Lastly, new volcanos may open out fissures in the crust of the globe, and thus give rise to new elaborations of calcareous matter. That some few of the alternations of sandstone, shale, and limestone, which we find among coal-fields are attributable to this kind of agency, no doubt whatever can subsist.

But the inquiry is very different, when we find certain beds of fluviatile origin alternate with others of marine origin ; as, for instance, shale-beds which contain numerous plants and the fresh-water unio, alternating with beds which enclose marine remains, such as encrinites, corallines, &c. &c.

As far as information is communicated by alternations of this character, no inference can be drawn, except that the land which formed the basin of a fresh-water lake had, by a terraqueous depression, become the bed of the ocean ;—or, *vice versa*, the land which formed the bed of the ocean had, by a subsequent elevation, become the basin of an inland lake.

But, when alternations of coal are included in our consideration, still more complicated views arise.

Coal has arisen from the decay of vegetables which grew on the spot ; generally in marshy sites, or in shallow waters. If, then, we find seams of coal alternating with sandstones, shales, or limestones of a fresh-water origin, no inference remains, but that oscillatory movements of the earthy crust must have taken place, by which land became submerged beneath the surface of a fresh-water lake, from which, by a subsequent elevation of the land, it has emerged, so as to give rise to a new Flora. And, in the case of coal-seams alternating with limestones of marine origin, which is also incidental to the coal-field of Mid-Lothian, a similar inference arises, that dry or marshy land had become submerged beneath marine waters, and had again arisen from the bosom of the deep, to be decked with a new flora, and with fresh verdure.

While all these inferences are suggested by the system of strata which I have described, there are still other important circumstances to be taken into consideration.

These alternations of elevation and depression have, in the coal-fields of Scotland, been conducted with a freedom from disturbance which is most remarkable. In few instances, except where local eruptions of trap-rock have prevailed, have I found derangements of strata marking the junction of marine and fluviatile deposits, or any intervening conglomerate strata, from which diluvial effects might be inferred. Near Bathgate, a limestone of marine origin may, at its junction with a fluviatile bed, be found to actually graduate into a fresh-water deposit. While the great mass of the rock encloses encrinites, corallines, &c., the unio appears in its uppermost bed, near its junction with an overlying bed of sandstone, filled with the remains of plants. East of Dunbar, also, no marks of violence whatever characterise the junction of two rocks, where, in the compass of a few inches only, we find the encrinites of a bed of limestone, abruptly, though quietly, overtopped by a sandstone containing calamites.

This varying, yet tranquil, alternation of sandstone, argillaceous shale, coal, and limestone, some of which are of fresh-water, and others of marine origin, becomes of difficult explanation. Nothing is more susceptible of proof, than that, during the carboniferous epoch, the crust of the globe was subjected to continued and prolonged oscillations of movement; and these indicate an ancient instability affecting our planet, of which, in reference to the comparative state of unchangeableness which now prevails, we can have little conception.

These circumstances of alternation have recently engaged much attention.—It has been shewn, that, during the secular refrigeration to which the globe is subject, the fractured portions of its crust would continue to adapt themselves to the diminishing capacity of its nucleus, in order to embrace it more closely; but it may be now explained, that, during this process, the same fractured portions would have their action modified by other circumstances, namely, unequal degrees of contraction, caused by thermometrical differences beneath the earth's surface. These I shall attempt to explain.

A theory to this effect, proposed by Mr DE LA BECHE and Mr BABBAGE, refers to the heated state of the nucleus of the globe, and its power of radiating heat. It also assumes, that the surfaces beneath rocks possess different powers of radiating heat. It follows, then, that the numerous fractured portions into which the crust of the earth has, by convulsions, been resolved, would, in reference to subjacent thermometrical differences, manifest unequal contractions;—that occasionally these unequal contractions would cause the sides of great fissures to press against each other, so as to induce sudden dislocations and movements;—but that more frequently very slow movements would be induced, too slow, perhaps, to be measured by time, attended with new positions given to great masses of rocks or strata. Large areas would be gradually thrust upwards along their lines of fracture,

while other fractured areas would be depressed ; so that, in this manner, extensive tracts of surface would be raised out of water, while other extensive tracts would be submerged.

But these effects, resulting from thermometrical differences communicated to the various fractured portions of the earth's surface, would scarcely harmonize with oscillatory movements, unless we include in our theory an alternation of conditions possessed at different times by such fractured portions. We must assume, that the particular thermometrical condition by which one fractured portion of the earth's crust was raised out of the water, and another was depressed, might become, at different intervals, liable to alternation ; otherwise we should fail in explaining why the bed of a fresh-water lake should have so sunk beneath its level, as to become covered with the waters of the sea ;—or why the same submerged tract should have again risen from ocean's depths, to resume its prior lacustrine condition ;—or why the very fresh-water lake itself should have been liable to similar oscillations ;—why, for instance, a given portion of land, covered with ferns or lycopodiaceæ, should have subsided beneath the level of lacustrine waters, or why it should have been again elevated above them, and again have afforded the soil for a renewed flora.

An explanation has been thus attempted of the remarkable alternations of fluviatile and marine strata, which are found in the Lothian coal-district, and of the equally remarkable tranquillity with which these alternations have been conducted. Mr DE LA BECHE, in reference to analogous phenomena which he has observed in newer formations, conceives, that particular situations are demanded to explain these deposits ;—situations where they have not been exposed to the destructive action of waves or powerful streams of water ;—and hence he argues, that fresh-water lakes, like those of America, appear the localities which offer the least difficult conditions. (*DE LA BECHE'S Theor. Geology*, p. 162, 320, &c.)

That the existence of large fresh-water lakes is necessary to explain the phenomena presented by the coal-fields of Scotland, I have long since advocated. (*See the Reports of the Proceedings of the Royal Society of Edinburgh*). The very great differences of level which subsist between the coal-measures of the Great Lowland Valley of Scotland, and the hills by which they are bounded, namely, the higher lands north of the Tay, the great Grampian chain, and the southerly grauwacke ridge which stretches from St Abb's Head to Galloway, are adverse to the notion that, during the carboniferous epoch, the continuity of spacious seas was only broken by occasional groups of studded islets.

If, then, it be conceded, that such elevated lands had very early risen above the level of the sea, they would rather point to the existence of large continents than of archipelagos of islets; and, in admitting the development of these lofty ridges, we must also infer that, acted upon by the rains of a humid atmosphere, they would naturally give origin to corroding water-courses, or rivers, and to large fresh-water lakes.

Accordingly, the existence of one or more of such fresh-water lakes is advocated as a very early state of the great valley of the Scottish Lowlands. But it is also admitted, that this flooded condition of the country might have been varied by islets; that even large tracts of dry land might have subsisted, and have been invaded by arms of the sea, or estuaries; and that while higher lands would encourage the growth of such coniferæ as the Craigleith fossils indicate, lesser plants, as ferns, &c. would find a soil amidst marshes or shallow lakes, or on the borders of deeper fresh-water basins.

During such a condition of the globe, the calcareous deposit of Burdiehouse was formed; new races of fish inhabiting fresh-waters were created, and among them the Megalichthys. The ocean also must have possessed its own peculiar races, and its

own finny monsters, which, in pursuit of their prey, would penetrate into fresh-water lakes, and even among the shallows of marshes.

These speculations may be extended to newer deposits.

In the strata succeeding to the Burdiehouse limestone, which consist of alternating beds of argillaceous or bituminous shales, of sandstone, and of thin seams of coal containing both vegetable and animal remains, we find that the calcareous deposit of Burdiehouse was but a temporary elaboration.

At Fountain-well, a thicker seam of coal (now wrought out) was once evident, covered by a bed of limestone, which contains marine shells, encrinites, corallines, &c. In reference to this, as well as to similar limestones of the south of Scotland, I may observe, that if the geologist expects to find these deposits of the same thickness as many in England, he will not fail to be disappointed. They occur in beds, perhaps not at the utmost more than forty or fifty feet thick, except in some places, and often alternating with sandstone and argillaceous shale. It is also remarkable, that not unfrequently three distinct alternations of this limestone will be found, as I have noticed between Musselburgh and Prestonpans. These alternations certainly indicate, that fresh-water lakes, or marshy tracts, were liable to be submerged by shallow seas, and not to be overwhelmed during a very prolonged interval beneath the waters of a deep ocean.

Phenomena of this kind are calculated to excite the greatest possible interest. They may be considered as affording unequivocal proof of the gradual, but momentous geological agency, which has been in operation. Partly from changes of level, occasioned by the internal commotions of the globe, and partly from circumscribed and local circumstances, new seas have in succession overflowed much of the land which had hitherto been the site of dense marshes, or tanks. The proof of these phenomena subsists in the beds of encrinal, coralline, and conchiferous limestones,

which greatly overtop the lacustrine deposits we have been contemplating.

The uppermost strata of the coal-measures of Loanhead, comprise alternating beds of sandstone, argillaceous and bituminous shale, along with ironstone bands, coal, and some little limestone; the workable beds of coal, two to ten feet in thickness, being about twenty-five in number.

By these beds numerous oscillatory movements are made known to us. Some of the alternations of sandstone, and argillaceous shale, might have been induced by matter drifting from different localities; and, of course, varying with such localities. But, in other instances, particularly where we find strata alternating with coal, we must refer the whole to corresponding oscillations of the earth's surface, by which a land covered with ferns and other plants has been submerged beneath a fresh-water lake, only to reappear;—and only to be succeeded by other alternate submersions and emersions, incidental to the early history of our planet.

SECTION X.—THE EFFECTS OF OSCILLATORY MOVEMENTS OF THE EARTH'S SURFACE, CONSIDERED IN REFERENCE TO THE ANCIENT VEGETATION AND ANIMALS DESCRIBED IN THE PRESENT MEMOIR.

That these oscillatory movements of the earth's surface must have caused corresponding changes in both vegetable and animal life may be expected. M. ADOLPHE BRONGNIART has frequently made observations on the differences of such plants as occur in the lower and upper beds of the carboniferous group. And, in the present instance, the *Sphenopteris affinis* and some few other ferns are, I suspect, confined to the inferior strata of the Lothian coal-fields.

With regard to the races of animals which inhabit waters, corresponding changes have been noticed. M. AGASSIZ has remarked, that, in a suite of strata belonging to any given formation, he has found few fish in a lower bed to agree as a whole

with those belonging to an upper stratum. Thus, for instance, the Burdiehouse limestone has a character essentially different from that of Wardie, which forms a higher stratum.

It is easy to suppose that, in the change which would cause a fresh-water lake to sink beneath the depths of the ocean, and, *vice versa*, to emerge and resume its fluviatile character, many races of animals, limited to definite conditions of water, must have been destroyed. But it would also appear, that their place has been supplied by successions of new races.

In the next place, a state of the earth's surface, subject to oscillatory movements, may afford an argument relative to another question which has been started. It has been supposed, from certain *a priori* reasonings, that during the carboniferous epoch, the air was so filled with carbonic acid gas as to be unfavourable to the respiration of animals possessing lungs. And hence it has been maintained, that no saurian animal during this period could subsist. If, however, the *Megalichthys* is really allied to the *Lepidosteus*, the researches of M. AGASSIZ have shewn that recent sauroid fish possess not only lungs, but likewise a trachea, and a glottis. The argument, therefore, of the air having been so filled with carbonic acid gas as to be fatal to the respiration of reptiles which possess lungs, becomes at least suspicious.

The question, therefore, remaining is to the following effect: If the *Megalichthys*, in common with the *Lepidosteus*, has possessed lungs, to what condition of the earth's surface might these lungs bear reference? The solution of this question can perhaps only meet with a satisfactory solution by an appeal to the actual habits of the recent *Lepidosteus*, which dwells among the large lakes of South America, but of which I can find no written account whatever.

In the absence of this information, it may perhaps be allowable to throw out a conjecture with regard to the oscillatory movements, which were going on upon the earth's surface during

the period when the Megalichthys lived ;—to movements by which land rose from some large lake, only to be again submerged, and by which alternations of submersion and emersion were often repeated. During such a state of our planet, lungs might have been given to sauroid fish, with the view of enabling them to support for a continuance the changes of element to which they were liable ;—that when they were left dry, they might be enabled to maintain life until again floated,—either by rains, or by the renewed effect of geological agency.

There is also another circumstance to be kept in view, namely, that as the remains of the Megalichthys are found in bituminous shale, and even in coal itself, it is evident that the animal must have frequented shallows, and wet marshes, among which he would have been liable to be left dry, and consequently to perish, unless for the provision of lungs.

That fish with analogous habits exist at the present day, may be learned from Dr HAMILTON's account of the scaly Cobojius of India, which lives among the extensive marshes of the Yazor district. This fish is possessed of great tenacity of life in the open air ; he is enabled to live many days without water ; and he is even endowed with a considerable facility of progressive motion on land.

NOTES TO SECTION X.

A speculation has been recently thrown out, which connects itself rather with the character of the watery fluid, than of the atmosphere in which these sauroid fish lived. Upon this subject, M. AGASSIZ has remarked, that if structure be indicative of habit, this sauroid tendency of the fish of the limestone of Burdiehouse will lead to further discoveries of the aqueous fluids of the globe, which were neither salt nor fresh ; as, by the character of the vegetation of remote periods, naturalists have been led to deduce a difference in the gaseous constitution of the atmosphere.—(*Report of the Edinburgh Meeting of the British Association of Science.*)

With regard to this observation I would suggest, that the argument regarding a half-saline state of waters, considered as prevailing over the whole ancient surface of the globe, is unsatisfactory, so long as it can be shewn that two distinct species of deposits, one apparently fitted for marine, and the other for fresh-water life, have existed. Proofs of this coexistence form the leading object of investigation in the present memoir.

And, with regard to a difference in the gaseous constitution of the atmosphere, when compared with its present state, I consider that such a difference might, to some little extent, have subsisted;—yet so little, as not to be capable of any geological proof whatever.

The argument for the air having been greatly charged with carbonic acid during the time when carboniferous strata were deposited, was first advanced by M. ADOLPHE BRONGNIART. Mr DE LA BECHE, in adopting this view, has undertaken a sort of origin and history of this atmospheric diffusion.

Mr DE LA BECHE's view is as follows: In a very early state of the globe, cracks or volcanic fissures in the earth's crust, formed the vents through which a large amount of carbon combined with oxygen, and, forming carbonic acid, made its constant escape into the atmosphere. The waters were so hot, that they could only absorb such portions of carbonic acid as were enabled to form compounds with the mineral matter rising above the level of the waters, and were sufficiently cool for the purpose. And hence it is argued, that, in consequence of the obstacles which would thus arise to the formation of carbonate of lime, at least in any very large proportion,—in consequence also of the elevated temperature of the water,—and in consequence of the difficulty of procuring disseminated oxygen, circumstances would arise unfavourable to the existence of numerous marine polypi, and shell-bearing animals, which require carbonate of lime in comparatively large proportions;—and thus, any carbonic acid thrown from the interior of the earth upon its surface, would, for the most part, remain in the atmosphere.

But, upon the earth becoming less heated, these conditions would necessarily change. The waters, in consequence of their being cooled down, would be enabled to take up more carbonic acid, which, when emitted from volcanic fissures, they would intercept. The carbonic acid, thus absorbed, would act chemically on many substances, and, among other actions, take up lime in solution, which, without this addition of carbonic acid, would have been insoluble in these waters; and hence, during this cooled down state of ancient seas, numerous marine animals would be called into existence, such as the shell-bearing Mollusca, Encrinites, and Corals, which would appropriate to themselves carbon; while an equal volume of oxygen would be liberated for their support, or would be thrown into the atmosphere.—DE LA BECHE's *Theoretical Geology*, pp. 298, 308, 313.

This is Mr DE LA BECHE's very rational theory. The question, however, still remains, whether the amount of oxygen thus liberated, would, after much of it had been arrested for the support of marine animals, form a residue capable, when thrown into the atmosphere, of contributing in any material degree to its purification. The theory shews little more than that any additional impurity would be checked, 1st, by the sea being so cooled down as to admit of an increased absorption of carbonic acid; and, 2^d, by the requisition of carbon for the creation of marine animals which had been called into existence, whence the formation of calcareous deposits, produced by such animal agency.

M. ADOLPHE BRONGNIART has conceived that the atmosphere, after it had re-

ceived its excessive proportion of carbonic acid, was purified by the development of the numerous plants, particularly of gigantic species, which were created during the carboniferous epoch, and for the support of which an extraordinary quantity of carbon must have been required.

All these views are unexceptionable so far as they go. There can be little doubt that the development of the abundant vegetation of coal-fields must have rendered solid much carbon which had existed in the atmosphere;—but, that this development was eventually, that is, during a still later formation of rocks, the cause of rendering the atmosphere fit for sustaining the respiration of reptiles possessing lungs, is another question; as we have no data whatever for ascertaining if such an amount of carbonic acid had subsisted, as to really render the atmosphere incompatible with reptilian vitality. On the other hand, the researches explained in the present memoir inform us, that an animal closely resembling the *Lepidosteus*, which M. AGASSIZ has proved to actually possess lungs, subsisted during a period when it was supposed that no animal possessing lungs could have possibly breathed.

SECTION XI.—SUMMARY OF THE EVIDENCE RELATIVE TO THE FRESH-WATER ORIGIN OF THE LIMESTONE OF BURDIEHOUSE.

The fresh-water limestone of Burdiehouse has at length been described, in which it has been shewn, that this bed is nothing more than an unit amidst many other fresh-water deposits, varying in their mineralogical character, and alternately deposited in the great Lowland basin of Scotland.

In concluding this memoir, I shall bring the fresh-water evidence to as severe a test as is compatible with geological reasoning, which must too frequently, in its very nature, be little more than analogical and circumstantial. In insisting upon a more rigid species of evidence, too many geological systems which we have carefully reared, would disappear “like the baseless fabric of a vision.”

The fresh-water evidence of the Burdiehouse limestone has hinged upon various points.

The first has been the absence of all mollusca and conchifera of acknowledged marine origin.

In recent times, the conchifera and mollusca of marine origin,

as well as of fresh waters, are distinctly recognised. We never witness seas inhabited by successive races of unios, or fresh-water rivers filled with a succession of coralline substances. If proofs have been brought forward that an interchange of element among animals dwelling in seas, or in fresh-water lakes or rivers, is possible, it is certain that such an existence could not long be maintained with immunity. Vitality would be rather tolerated than fostered, and this would be shown in the gradual diminution and eventual obliteration of the races of animals thus subjected to an interchange of element,—which fact at least indicates, that mollusca and conchifera, in their distribution, bear reference to different mediums of saline and fresh water for their prolonged support.

This principle I have analogically applied to the limestones of the carboniferous epoch. If we find that marine mollusca and conchifera are present in most limestones in the vicinity of Edinburgh, yet are absent in the limestone of Burdiehouse, to what other conclusion does this absence point, but that a condition of waters had prevailed, during the time of this deposit, unfavourable to the vitality of marine animals? And hence the supposition, that this condition was a difference of element, similar to that which still prevails, namely, fresh water, hostile to the prolonged existence of pelagic conchifera and mollusca.

A second point upon which the evidence of the fresh-water origin of the Burdiehouse limestone has hinged, is circumstantial rather than analogical.

The circumstantial evidence is to the following effect :—That the calcareous deposit of Burdiehouse must have taken place in a depression, or basin, perfectly surrounded with a dense vegetation, which has been washed into inland waters. But this circumstance would of itself prove little, as we may easily suppose that an estuary, or arm of the sea, might have stretched through a tract where a dense vegetation has prevailed. But when, in connection with a perfect absence of all acknowledged marine remains

whatever, we find plants enclosed in a calcareous deposit in the greatest profusion imaginable, what conclusion remains, but that such a deposit is more indicative of a fresh-water river or lake, than of a sea or estuary?

Other points of evidence are perhaps less forcible, although they all tend to the same conclusion.

We find, for instance, that if the inland waters which deposited the limestone of Burdiehouse, were actually unfavourable to the existence in it of acknowledged marine mollusca or conchifera, they were not unfavourable to countless myriads of entomostraca, one genus of which, the *Cypris*, is the recent inhabitant of fresh-water marshes; and it may be fairly suspected that other genera associated with it were equally so.

I will not at present dwell upon the presence of the fish discovered in the Burdiehouse limestone, although some of the genera are found enclosed not only in such sandstones and shales as are crowded with plants, but even in coal itself. I shall hereafter shew, that if their presence does not afford an analogical proof, it is at the least circumstantially presumptive, that the Burdiehouse limestone has had a fluvatile origin.

In short, the evidence, in a general point of view, leads to the following conclusion.

There are, it is well known, numerous deposits of limestone belonging to the carboniferous group of rocks, in which, to the exclusion of any vegetables of a Tropical Flora, nothing but marine products, such as corallines, or acknowledged shells of genera hitherto found in open seas only, have been discovered. With a calcareous deposit of this kind, the comparison of another calcareous deposit, destitute of all corallines or marine shells whatever, yet containing, in an abundance perfectly remarkable, the plants of tropical marshes, along with the entomostraca of marsh waters, can surely lead to no other conclusion but the following:—That while the first formation must have taken place

in a pelagic bed analogous to one of recent times, the other must have been the result of a fresh-water deposit, which, while it was no less hostile to the growth and increase of marine shells or corallines, must have flowed through marshy tracts, wherein grew all the plants observable in our coal-fields. Accordingly, in comparing the limestone of Burdiehouse with such a limestone as we find at Aberlady, which appears to be formed of one almost uninterrupted aggregate of coralline productions, or with the contiguous encrinitic limestone of Gilmerton, or with a zone of limestone filled with numerous varieties of marine remains, which crops out in a line of nearly S.S.W. to N.N.E., from Bathgate to Linlithgow, what doubt can remain, that while the limestone of Burdiehouse is of fresh-water origin, that of the other sites enumerated must be of marine origin?

But it is not with such unequivocal marine deposits, that I would dwell long for a comparison, as the line of demarcation is but too obvious. I would prefer drawing a line of difference with such a limestone as I have studied in Derbyshire, which is illustrative of an estuary.

The lowest visible portion of the great mass of Derbyshire limestone may be seen at Sherbrook, near Buxton. It is very crystalline, unstratified, and it contains no organic remains whatever. In the beds above it stratification commences, and the limestone encloses numerous encrinites, corallines, producti, &c. In still higher beds, such as we find at Ashford, indications are rather afforded of a marine estuary, than of an uninterrupted or open sea. Although this limestone abounds with acknowledged marine productions, among which corallines are pre-eminent, I discovered that in some sites the plants of coal-fields were mixed with them, although very sparingly. Among various plants which I collected, one of them was the *Sphænopteris artemisiaefolia* of ADOLPHE BRONGNIART (See Pl. 46. of his "*Histoire des Vegetaux Fossiles.*") Other species, some of them new, and perhaps

of new genera, remain to be described. I also obtained Ichthyodorulites, along with palatine and incisive teeth, severally referable to M. AGASSIZ's family of Cestraciontes. At the same time, I did not find in the limestone any entomostraca, or any remains of smaller fish whatever, as at Burdiehouse.

In comparing, then, the limestone of Burdiehouse with that of Ashford, it will be found that most assuredly these two approach the most in character to each other. Yet still, in forming a table of comparison, such as the following, which I offer from my own personal observation, the line of demarcation will be sufficiently apparent. For instance,

THE LIMESTONE OF ASHFORD CONTAINS	THE LIMESTONE OF BURDIEHOUSE CONTAINS
1. Encrinites, Corallines, Producti, Orthoceratites, &c. in infinite abundance.	1. No marine remains whatever.
2. Plants, which are found very sparingly, and in a few sites only.	2. Plants in the greatest possible profusion.
3. No Entomostraca whatever discovered.	3. Entomostraca, in such abundance as to occasionally impart to the limestone an oolitic character.
4. No remains of small fish.	4. Numerous small fish, as the Palæoniscus of coal-fields, &c.
5. Remains of fish referable to the family of Cestraciontes (AGASS.). Genus not yet ascertained.	5. Remains of fish referable to the family of Cestraciontes (AGASSIZ); <i>e. g.</i> the Gyracanthus formosus.
6. Other animal remains, which have been referred to Saurian reptiles. Their true character is hitherto unknown.	6. Remains of large Sauroïd fish; <i>e. g.</i> the Megalichthys.

The foregoing table of comparison, which, for the sole purpose of instituting, I revisited Ashford in Derbyshire, will, I trust, be regarded as important. From a consideration of it, the following inferences may arise:—

1st, While the great abundance in which Corallines, Encrinites, Producti, or Orthoceratites, are found in the limestone of Ashford, prove that it was unequivocally a marine formation, the

absence of all such remains in the Burdiehouse deposit shews, that its waters were unfavourable to the manifestation of marine mollusca and conchifera.

2dly, While the comparatively sparing quantity of plants to be found in the limestone of Derbyshire rather indicates that they had been washed into an estuary, or diffused through a sea near the influx of rivers, the immense abundance of plants contained in the Burdiehouse limestone, prove the actual flowing of some river, or fluviatile expanse, through a marshy tract, in which ferns and lycopodiaceæ flourished.

The two foregoing points of difference form the great grounds of distinction between the limestone of Ashford, considered as the deposit of an estuary, and the limestone of Burdiehouse, considered as a pure fresh-water deposit. Other circumstances point to similar grounds of distinction, though perhaps less decisive.

3dly, While the limestone of Ashford contains no entomostraca whatever, they are found in such abundance in the limestone of Burdiehouse, as to occasionally impart to it an oolitic character.

Now, the presence of these entomostraca can scarcely be considered decisive so long as we know that marine waters can exhibit Cythereæ, and that the limestone of Burdiehouse encloses many different kinds of entomostraca. The circumstance, however, of the Cypris being found in the Burdiehouse limestone, is assuredly presumptive of this deposit having been formed among the stagnant fresh-waters of ancient marshes.

4thly, While the Ashford limestone encloses no remains whatever of such small fish as are abundant in the sandstones, bituminous shales, or bands of limestone, which contain plants and fresh-water unios, but in which all marine remains are absent, these fish appear most abundant in the limestone of Burdiehouse, presumed to be of fresh-water origin.

This circumstance, also, considered as an argument, is not free from ambiguity. Although I conceive that, during the carboniferous epoch, smaller fish dwelt more in fresh-water lakes or rivers, whither they were pursued by larger finny monsters, I should be sorry to affirm that they might not frequent estuaries, or arms of the sea. One genus of *Palæoniscus* is found in the limestone of Burdiehouse, and another in the later formation of the magnesian limestone,—which last, I presume, is of marine origin.

5thly, Remains of fish referable to the family of the Cestraciontes (AGASS.), appear both in the estuarian deposit of Ashford, and in the fluviatile deposit of Burdiehouse. Now, the appearance of these large finny monsters in each formation, at least countenances the opinion which I have advanced, that estuaries, as well as fresh-water lakes or rivers, were visited by them in quest of their prey.

At the same time, the genera of Cestraciontes found at Ashford and at Burdiehouse, are not the same. During the spring of the present year, I procured large bony rays, as well as large palatine and maxillary teeth, from the limestone of Ashford; but the bony rays widely differed from the character of such as have been referred to the *Gyracanthus formosus* of Burdiehouse.

6thly, While the limestone of Burdiehouse encloses remains of the immense and scaly *Megalichthys*, it is only a probable conjecture that similar relics might have been discovered at Ashford. (See the Notes to Section XII. of Part. I.)

It follows from these premises, that, while a limestone which contains marine mollusca, &c. and, along with these remains, the plants common to coal-fields, together with the entomostraca of marshes, may be regarded as an estuarian limestone, other circumstances, although they may point to the same conclusion, are either less decisive, or ambiguous.

As for the remains of Cestraciontes, (and perhaps of the Megalichthys,) which appear in more than one description of carboniferous limestones, they point to estuaries, no less than to fresh-water lakes, as having been in primeval times frequented by large animals in quest of their prey.

The foregoing researches shew,—

1st, That it is by the presence or absence of acknowledged pelagic mollusca, corallines, &c. that indications are afforded of the great difference between fresh-water and marine deposits.

2dly, That if, along with marine mollusca or corallines, we find the plants of coal-fields in a quantity comparatively small, an estuarian limestone may be inferred. And,

3dly, That if marine mollusca or corallines should be entirely absent in a limestone, and if plants should be abundantly found in it, an indication would be afforded of a calcareous deposit which took place amidst the fresh-water rivers or lakes of primeval marshes; which indication would be still more favoured, if we should find, in addition, recognised genera of fresh-water shells, the entomostraca of stagnant marshes, or the fish incidental to coal-fields.

It is however admitted, that the presence of fish is an ambiguous criterion. The smaller fish of lakes, or rivers, are known in recent times to venture into estuaries, while larger fish enter fresh-water rivers, or lakes, in pursuit of their prey.

From these conclusions it is evident, that while a broad line of demarcation subsists between marine and fresh-water limestones, it is by no means impossible that limestones of an estuarian and fluviatile formation may, in some cases, be more difficult to distinguish, and particularly, when it is kept in view, that, from a remote period of the globe, communications between rivers and seas must have subsisted, as at the present time. Thus, during the actual state of our globe, the Ganges, as we approach close

to its source, teems with fresh-water animals exclusively ; but, in following it to its junction with the sea, marine products, even far from its mouth, begin to appear. Yet the Ganges, notwithstanding any partial ambiguity of its products, possesses not the less a fresh-water character.

Hitherto, however, I have not found the slightest traces of marine mollusca or corallines in the limestone of Burdiehouse ; and hence, I am not induced to consider it as any thing but a pure lacustrine formation ; and if any marine remains should in future turn up, which I do not expect, they would be so small, in comparison with the very abundant indications afforded of an opposite state of the waters which had yielded this deposit, as to merely indicate its original connection with an ancient sea, and nothing more ;—which last supposition I have, from a different description of evidence, never been once inclined to doubt.

That seas should have been actually synchronous with a fresh-water deposit, is indeed, as I have shewn, what might be naturally expected. Few rivers or lakes subsist, which do not maintain such a communication. I am, therefore, prepared to expect, that the remains of such large fish as are found in fresh-water deposits, may also be discovered in marine deposits, analogous, in fact, to what takes place at the present day in numerous parts of the globe, where we find the fish which inhabit seas penetrating many hundred miles up large rivers in quest of their prey, as, for instance, towards the source of the Ganges.

It is also very probable, when we consider the frequent oscillatory movements to which the crust of the earth was exposed during the carboniferous epoch, that the fish which were then created might possess an adaptation of animal structure calculated to enable them to sustain any occasional change of element caused by terraqueous elevations or depressions ; for M. AGASSIZ states, that, among the fish of the earlier formations of strata, he has not observed those marked characteristics of structure, which, in later times only, point out these animals as distinct inhabitants of salt or of fresh water.

These considerations prove to us, that if we would distinguish between the marine and fresh-water formations of very early epochs, we must form our judgment less upon any insulated relics which may turn up, than upon an assemblage of organic remains, considered in reference to a combination of geological circumstances.

I shall, lastly, endeavour to sketch the true character of the limestone of Burdiehouse, in reference to the beautiful speculations of Mr DE LA BECHE, upon the quietness of deposition incidental to the formation of more ancient strata.

Springs charged with the carbonate of lime, and issuing from profound crevices incidental to one of the more early fissured states of the earth's crust, had mingled their mineral contents with the waters of some river, or of some fluviatile expanse, which had sluggishly flowed through a marshy tract, principally overrun by the creeping and gigantic stems of the mysterious Lycopodiaceæ, and by a dense undergrowth of ferns, among which the luxuriant growth of the *Sphenopteris affinis* was particularly favoured. And hence the production of a calcareous deposit, which, in gradually and tranquilly congealing, had preserved to plants possessed of such tender form and structure as the lesser ferns, all the delicate divisions of their pinnæ, or pinnulæ, as well as all the slender and linear character of their lobes, unaffected by the violence of currents, or by any of the atmospheric commotions which a later and less heated condition of the globe has invoked.

So great, in fact, is this state of preservation, that we are irresistibly carried back to a period, when, in conformity with the distribution of a thermal ocean over various parts of the globe, equatorial and polar states, by being rendered uniform, would so adjust the temperature over the whole surface of our planet, as to induce a quietness of deposition, which no formation perhaps more happily elucidates than THE FRESH-WATER LIMESTONE OF BURDIEHOUSE.

NOTES TO SECTION XI.

Having at length carefully drawn every close and tedious distinction of which I conceived a fresh-water question of this kind was susceptible,—more, in fact, to combat the objections with which I have been assailed, than to aid in my own conviction,—a perfect weariness of fresh-water deposits, and of ancient lakes or rivers, has more than once tempted me to exclaim, in too literal a strain, with the Mantuan poet,

Claudite jam rivos, pueri : sat prata biberunt.

But this long discussion, in which I have embarked relative to the fresh-water origin of the limestone of Burdiehouse, has not been uncalled for. I have been desirous that my memoir should embrace the confutation of every charge upon which I have been attacked. I am unwilling to allude to any particular attack, but as silence has but too often been interpreted as an admission of defeat, I must impose upon myself the very annoying task of noticing a few animadversions.

The first objection strongly urged against me was that the limestone of Burdiehouse had not a fresh-water but a marine origin.

With regard to this counter opinion,—after the numerous facts which I have brought to bear against it,—I will not again combat the objection, that the deposit of Burdiehouse was less under the dominion of the Naiads than of Neptune ; nor will I disturb the opinion publicly expressed against me by the President of the Edinburgh Wernerian Society, for whose old Neptunian predilections I can make every allowance.

In the second place, my account of a lacustrine limestone existing among the carboniferous group of rocks was arraigned on the score of originality.

In order that the force of this charge may be properly estimated, some previous explanation may be necessary.

Various thin seams, named bands of fresh-water limestone, are common throughout the whole of the coal-fields of Scotland, and scarcely need be enumerated. Many of them contain fresh-water Unios. Seams of this kind I have observed near Old Cumnock, and other places.

These bands of limestone cannot fail to be familiar to every geologist who has studied coal-measures. From their having come within my notice, I conceived, as well from this as from other analogies to which I have already alluded, that the existence of considerable beds of fresh-water limestones, to which the name of bands could not apply, was a rational expectation. That my expectation has not been disappointed, the present researches have, I trust, satisfactorily proved.

In reference to one of these bands of limestone, the originality of my discovery has been arraigned upon the strength of a passage, which appears in the Proceedings of the Geological Society of London, by Mr MURCHISON, incidental to an account of the coal-fields in the neighbourhood of Shrewsbury. It is stated, that “ three thin beds of coal are for the most part observable, and the deposit is distinguished by

an included *band of limestone*, similar in mineral aspect to the lacustrine limestones of central France, and containing minute shells, referable to fresh-water genera."

Mr MURCHISON has publicly pointed out to me this passage, which, from my residence abroad, I had not seen, but which I am sure, if I had read, would have escaped my recollection, from its apparently trivial importance.

The reply which I have to make is, that if my discovery of extensive beds of lacustrine limestone is to be superseded by mere bands of fresh-water limestone, Mr MURCHISON himself has been anticipated by other writers. The Rev. Mr URE, in his *History of Rutherglen*, written at least forty years ago, states, in reference to certain fresh-water muscles, or unios, enclosed in a band of limestone, that "the shells were commonly entire, and were *probably produced in fresh water*."—*History of Rutherglen and Kilbride*, p. 311.

Granting, however, that Mr MURCHISON's limestone is thicker than what is usually meant by a *band* of limestone, the various limestones which I have enumerated are not, like his, contained *within* beds of coal, but, on the contrary, form considerable deposits *beneath* beds of coal. This difference has been remarked by Mr DE LA BECHE.—*Geological Researches*, p. 319.

But waving these very subordinate considerations, I shall state in my own defence, that my memoir was drawn up at a time when many British geologists were inclined to admit, with a writer of the first weight, that no instance had yet been discovered of a pure lacustrine formation of the carboniferous era; and that although there were some instances of shells, apparently fresh water, which might have been washed in by small streams, they did not by any means imply a considerable extent of dry land. (See *LYELL's Principles of Geology*, 1st Ed. vol. i. p. 130, and vol. iii. p. 15.)

My own discovery, however, of the fresh-water character of the limestone of Burdiehouse, in conjunction with that of other similar limestones of still greater thickness and extent, viz. at Calder and elsewhere (See the Supplement to this memoir), have, I trust, tended to set geologists right upon the question of pure lacustrine deposits existing during the carboniferous epoch.

But after all,—these disputed claims of originality may neither belong to myself nor to any other British geologist. The far older speculations of M. DELUC and of M. ALEXANDRE BRONGNIART, refer all the varieties of strata comprehended in coal-measures to a lacustrine origin; while their theory upon the alternation of these strata with marine deposits has, in some few respects, coincided with the principles which I have sought to establish in the present memoir.—(*Tableau des Terrains, par BRONGNIART*, p. 280, &c.)

With a third charge I was industriously assailed during the meeting of the British Association of Science at Edinburgh. It was contended that I had given an erroneous position to the limestone. My present memoir will however show, that the view which I originally entertained on this question remains unaltered. I went over the ground with some of our most distinguished geologists, among whom was Dr

BUCKLAND, who compared very critically the section which I had given, with his own observations made upon the spot.

Dr BUCKLAND likewise examined with the greatest attention the Roslin, or Hawthornden sandstone, in order to set himself right with regard to a notion entertained, of its belonging to the new red sandstone, rather than to the coal-formation; an objection, which it was supposed (though I could not myself see the force of it) would materially affect the position which I had assigned to the limestone of Burdiehouse. Accordingly, in conducting Dr BUCKLAND to the grounds of Hawthornden, with the view of examining the best natural section which could be afforded of the rock in question, we were so fortunate as to meet with the outcrop of the Jewel-coal resting conformably upon the Hawthornden sandstone. The reference, therefore, of this deposit to any other formation, except that of the carboniferous group, may be considered as set at rest. The opinion which I have myself expressed is, that the Roslin sandstone may possibly be found to rank as one of the more ancient members of the carboniferous group; and if this geological position be confirmed, it would make the Stoneyhill coal, in which the remains of large sauroid fish have been abundantly found, an older bed than is usually supposed. But this suggestion I throw out, with submission to another judgment of no little weight. No one is better acquainted with the strata of the Scottish coal-fields than Lord GREENOCK, to whom the merit of discovering the animal remains of the Stoneyhill coal is due.

In the incidental allusion which I have made to this nobleman, I hope for indulgence in the opportunity thus afforded me, of rendering justice to my own feelings, in acknowledging the very kind encouragement which I have uniformly received from his Lordship's hands, during the course of these researches. A zeal, such as Lord GREENOCK evinces, in the science which he himself so successfully prosecutes, affords an example, when united with rank, too illustrious not to render it an object of popular imitation. Nor can the example fail to render the most essential services to the cause of geology in Scotland.

CONCLUSION.

IN concluding this long memoir, I should be most ungrateful not to acknowledge the very deep obligations which I have been under to the Royal Society of Edinburgh, for their flattering attention, as well as other marks of kindness.

I also feel proud in the opportunity of having brought forward these researches before a Society, whose earlier members, now no more, are associated with the brightest period of the history of Geology. The appearance of a HUTTON in the field, gave token of an emergence from the darkness which pervaded the geology,

not of this country alone, but of every region in Europe. This was followed by the exertions of a HALL and of a PLAYFAIR, who, in their days, were towers of strength. The researches of these philosophers, together with the important labours of some few of their Neptunian competitors, which, though conducted upon erroneous and illogical principles, embodied invaluable facts, reflect a high lustre on the active interval of Scottish geology, which has prolonged itself to the date of the important writings of a MACCULLOCH and a BOUE'. If an interval of inertness has followed, Industry now promises to resume her sway. The exertions of the Highland Society, conjoined with the late proceedings of the British Association of Science, severally shew, that the Genius of Scottish Geology is awakening from his slumbers, like a giant refreshed.

SUPPLEMENT.

The great extent to which my Memoir has reached upon the fresh-water limestone of Burdiehouse, precludes me from doing any thing more than throwing into the form of a Supplement, notices of other fresh-water limestones in the vicinity of Edinburgh, brought before the Royal Society, although I possess materials for a description of them, almost sufficient to fill a volume.

It was a desideratum of no little moment to learn, whether fresh-water limestones, similar in their geological character to that of Burdiehouse, did not occur in other localities of the coal formation of Scotland, or even elsewhere.

Having this object in view, I did not content myself with merely visiting the neighbourhood of Edinburgh; I travelled at different intervals several hundred miles over various districts of the Basins of the Forth, the Tay, and the Clyde, and have even availed myself of the occasion which a journey to England afforded me of exploring certain parts of Derbyshire, with the self same view. My labour has not been directly, but indirectly successful. If I have not found these fresh-water limestones so abundant as I expected them, I have still been enabled to assign to them a few localities, and the acquisitions which I flatter myself it will be hereafter found I have made to our knowledge of the general relations of the strata of the south of Scotland, conjoined with the discovery of a fresh-water bed of rather a different character, but of an interest fully equalling that of Burdiehouse (I allude to the limestone of Kirkton near Bathgate), far more than recompense me for toils which have been unremitted.

1st, The Fresh-Water Limestones of Calder.

At East Calder, and to the south-west of Mid-Calder, the limestone which is there quarried appears, like that of Burdiehouse, to have a fresh-water origin. Its strata have undergone great derangement, and dip in various directions. In one of the quarries of East Calder, where a good section is exposed, the lowest rock is said to be sandstone, above which the following strata may be enumerated in an ascending order :—A yellowish coarse limestone, 16 feet thick ;—limestone, 43 feet thick, in which vegetable remains are contained, such as are usually found in coal-fields, and, along with these, scales of the *Megalichthys* have been discovered ;—nine feet of a very bituminous shale, part of which burns readily, mixed with ironstone ;—shale (named Blaes) 16 feet ;—and, at the top of the series, an alluvial covering of clay, sand, &c. in which large boulders occur.

2d, The Fresh-Water Limestone of Burntisland.

A very deep-seated bed of fresh-water limestone is to be found in the road from Newbigging to Burntisland in Fifeshire. It also crops out on the north of the Bin Hill. It is comparatively a small bed, being at Newbigging not more than eighteen feet thick. Plants as well as Coprolites are contained in it.[†]

I have collected numerous details regarding this very deep seated deposit, but, as I have not space to enter into them, I shall merely remark, that its geological situation appears in a section of the beds exposed between Burntisland and Seafield town, which has been published by Dr BOUE'. This excellent geologist did not lose sight of the important fact that the limestone of Burntisland contained the remains of plants. (*See Essai Géologique sur l'Ecosse, par A. BOUE', p. 472.*)

3d, The Fresh-water Limestone of Kirkton, near Bathgate, indicative of ancient Thermal Waters.

I regret most exceedingly, that I have only space to give a mere outline of this very interesting deposit.

From Bathgate to Linlithgow, a distance of about six miles, a long line of fissure extending from S.S.W. to N.N.E. may be traced, by which deep seated beds of limestone are brought to view. Near Linlithgow an eruption of trap occurs, but as outcrops of limestone reappear in the noted quarry of Limekilns in Fifeshire, near the seat of the Earl of ELGIN, it is probable that the line of fissure has been prolonged across the Firth of Forth in the same direction of N.N.E.

A mile or two to the east of Bathgate, at Kirkton, we find that a very considerable outbreak of greenstone has occurred. Close to it on the west appears the limestone of Kirkton. By this contiguity we are assured, that the limestone must have been elaborated within the immediate sphere and influence of an extensive volcanic eruption. The consequence has been, that one of the most unique formations of

which Great Britain can boast, has been formed, indicative of thermal waters belonging to the carboniferous epoch.

A decidedly fresh-water formation is there exposed, which is characterized by the absence of all marine shells, corallines, &c., and the presence of the well-known vegetable remains of the coal-formation.

But the remarkable circumstance in this limestone is its mineralogical character, indicative of the very powerful chemical action under which it was elaborated.

This chemical action appears to have been so energetic, as to have caused such miscellaneous earthy matters as are found to enter into the composition of an impure limestone, like that of Kirkton, to separate into laminæ, and to assume a sort of striped disposition, (*rubané*, as it is also named), resembling what I have occasionally noticed in Auvergne, where tertiary strata have come into contact with volcanic rocks. The strata, for instance, of Kirkton quarry are composed of distinct and alternating thin laminæ, some of them being of remarkable tenuity, variously consisting either of pure calcareous matter, of translucent silex, resembling common flint, or of a mixed argillaceous substance, which approaches to the character of porcellanite, or of ferruginous, or even of bituminous layers, originating probably from vegetable matter.

Upon one of these very thin aluminous folia, which I have compared to porcelanite, I observed the impression of a Fern, apparently of a *Pecopteris*, which was delineated upon it like a painting upon porcelain.

It is also remarkable, that the mixed ferruginous and carbonaceous layers which enter into the structure of the limestone, often assume a sort of blistered appearance upon their surface, as if from the effect of heat.

Another effect of ancient thermal waters, may be inferred from the very singular warping which the strata have undergone. The wavings which they exhibit are extremely remarkable upon a large scale, and it is no less surprising that the same contortions should be evinced, even to a far greater degree, in small hand specimens of the limestone. That this effect has been aided by a lateral as well as superjacent pressure of eruptive rocks of volcanic origin, is highly probable.

Some part of the limestone, again, shews other species of character. I collected a specimen, in which a structure, globularly concretionary, was observable, the surface having, at the same time, a mammillary appearance. This is another proof of the powerful chemical action which was excited when these limestone beds were formed.

All these appearances tend to the hypothesis, that the calcareous beds of Kirkton were elaborated under the action of great heat; or, in other words, that they had their origin in deep fissures, intimately connected with a volcanic focus.

But this view does not, in fact, demand any hypothesis whatever. An interposed mass of volcanic tufa, of a green colour, which occasionally assumes the compactness of greenstone, is developed among the higher beds of the deposit. It has an elongated, wedge-shaped appearance, and it is extended in a direction nearly conformable to the general bearing of the strata. The greatest thickness which it ex-

hibits may be estimated at two to three yards, but in tracing it to the part of the quarry where it disappears, it may be observed to thin off to as many inches.

The inference is, that the calcareous matter was elaborated on the site of Kirkton in the form of hot springs, probably at the time in a state of ebullition. I need not add, that this is a phenomenon perfectly familiar at the present day in districts where the volcanic agency is still in activity.*

This limestone, as I have remarked, contains plants, among which is a beautiful *Pecopteris*, which I have transmitted for description to Professor LINDLEY and Mr HUTTON, to be inserted in their British Flora.

It could scarcely be expected that this limestone should contain any animal remains, but, to my surprise, some most singular creatures have turned up

No fewer than five specimens were at one time discovered of a crustaceous animal of extraordinary large dimensions. Unfortunately, these specimens in their broken state were soon dispersed. A very able naturalist of Glasgow, Dr SCOULER, at present Professor of Mineralogy in the University of Dublin, obtained the sight of a portion only of one of these animals, which he described under the name of *Eidothea*. (*Edinburgh Journal of Natural and Geographical Science*, vol. iii. p. 352.)

When my account of the limestone of Kirkton was made known through the journals, public attention was directed to its singular character, and, as a consequence, more of these dispersed remains were brought to light, particularly by Dr REID and Dr SIMPSON, severally of Bathgate. The last named gentleman allowed me to exhibit the relics in his possession at a Sectional meeting of the British Association of Science; and Mr SMITH of Jordanhill then brought forward the head of the animal described by Dr SCOULER.

In Plate XII. figs. 1. and 2. shew both sides of the animal. Fig. 3. is the head alluded to; while figs. 4. and 5. are the two sides of an extremity, apparently referable to the same specimen.

Upon this occasion Mr TORRIE of Edinburgh was so obliging as to place in my

* In concluding my mineralogical account of this deposit, I would observe, that my intelligent young friend, Dr SIMPSON of Bathgate, was the first to inform me, after the reading of my paper, that the limestone of Kirkton had been noticed in an article by Dr FLEMING, published in the *Edinburgh Journal of Science* for April 1825, (p. 307.) In this paper, a brief allusion is made to the siliceous laminae of the limestone, as well as to its botryoidal and mammillary structure. It is also stated, that "several trunks of trees with their branches" had turned up, in which concentric zones and perpendicular fibres were visible. Dr FLEMING's remark, that this limestone "encloses the remains of those marine animals which are common in the limestones of the coal formation," I consider as a mistake. The memoir is entitled, "On the Neptunian formation of Siliceous Stalactites." It is almost entirely theoretical, being a defence, in reference to siliceous developments, of the doctrine taught by WERNER.

I may also add, that since an abstract of this memoir appeared in print, Mr MACLAREN of Edinburgh has published (in the *Scotsman*) some very ingenious observations upon the trap-rocks in the immediate vicinity of this thermal deposit, in which their stratified character is advocated. I am sorry that the extreme length of my memoir prevents me from entering into an explanation of his views, and from expressing my own opinion regarding them.

hands Dr HARLAN's account of the Eurypterus of North America, to which the Kirkton specimens were readily referred.

The Eurypterus is assigned by Dr HARLAN to the class Crustacea; and to the order of Branchiopoda. His description of the genus Eurypterus is as follows:—

Character of the Genus.—"Caput a thorace non distinctum: os ignotum: oculi duo, sessiles, distantes, lunati: abdomen elongatum, posticam versus extremitatem sensim gracilius, segmentis transversis subimbricatis divisum. Pedes octo; duo utrinque antici branchiferi, duo utrinque postici maximi, omnes lamellosi."

Dr HARLAN's specimens were obtained from a "transition calciferous sand rock" of Westmoreland in the Oneida county of New York. He has described two fossil species, the Eurypterus lacustris and the E. Remipes. (See Plate XII. fig. 6. and 7.)

The head of the Eurypterus of Kirkton (see Plate XII. fig. 3.), which differs in many respects from the American specimens, exhibits a physiognomy so human like, that the quarrymen attributed it to some degenerate offspring of Adam. For this reason, as well as in reference to the sort of examination which it seemed to invite, the animal might have been stiled the Eurypterus phrenologicus.

A more suitable specific title is, however, suggested. In honour of the naturalist who has described in a satisfactory manner the only fragment, namely, the head and a small portion of the abdomen, which came under his observation, I propose, to name the Eurypterus found at Kirkton, the EURYPTERUS SCOULERI.

I consider the Eurypterus Scouleri to be distinguished from other species, by the prolonged eminences intervening between the eyes, which at their apex form an angle wherein appears a central tubercle;—also by the small acutely angular protuberances, like spines, which are diffused over the surface of the head beneath the eyes. The character of the feet cannot be given, as no vestiges of them, except very slight ones, have turned up*. Perhaps, a last distinction is the greater size of the E. Scouleri, which may be learned from the following table of comparison:

	EURYPTERUS LACUSTRIS.	EURYPTERUS REMIPES.	EURYPTERUS SCOULERI.	
			Larger Specimen.	Smaller Specimen.
Length of the head,	1 $\frac{1}{4}$ inch.	1 inch.	6 inches.	5 inches.
Breadth of the head,	2 $\frac{1}{4}$...	1 $\frac{1}{2}$...	8 ...	6 $\frac{1}{2}$...
Distance between the eyes,	1 ...	$\frac{3}{8}$...	1 $\frac{1}{2}$...	1 $\frac{1}{16}$...
Breadth of the body,	2 $\frac{5}{8}$...	1 $\frac{5}{8}$...	8 ...	5 ...
Total length,	5 ...	3 $\frac{3}{4}$...	17? ...	13 $\frac{1}{4}$? ...

The Geological Relations of the Kirkton Limestone.—Above this deposit, we find beds of very loose friable shale with ironstone bands, some of which are alternated with its upper strata. These shale beds, composed of pure argillaceous matter, appear to have undergone few or no alterations from the action of heat.

* In concluding this account of the Eurypterus, I beg to express my best thanks to Dr SIMPSON of Bathgate, for giving me the opportunity of describing the specimens in his possession, as well as to Mr SMITH of Jordanhill, for the loan of the specimen in the Andersonian Museum of Glasgow.

The whole of the limestone strata dip generally towards the west, or north-west by west, at angles varying from 24° to 28° .

To the west of the limestone is much covered ground, but, as far as I could learn, the strata succeeding to this fresh-water deposit consist of alternations of sandstone and shale.

But, at a little farther distance, are limestone beds, containing marine shells, dipping in like manner to the west, and thus shewing that they are the uppermost, and, consequently, later strata.

The Kirkton limestone, in common with newer limestones of marine origin, appears to have not only undergone an elevation subsequent to the period when it was consolidated, but to have also had its tilted and upturned strata covered over with subsequent volcanic eruptions of felspathose trap. This trap is superimposed upon the limestone of several quarries extending from Bathgate to Linlithgow, and it occasionally assumes a prismatic form. More frequently, however, it appears under the character of a decomposed wacké. From six to fifteen feet of this substance, in perpendicular depth, repose upon the upturned edges of the Kirkton limestone.

This overlying mass must have originally covered a considerable tract of space in the form of a lava.

In concluding this account I must observe, that the limestone of Kirkton particularly recommends itself to the attention of all who are anxious to trace, in the various effects produced upon rocks, the influence of central heat. I have already transmitted specimens of this limestone to a distinguished philosopher, M. DE LEONHARD of Heidelberg, who, more than any other geologist, has successfully prosecuted this important branch of investigation.

Description of the Plates belonging to this Memoir.

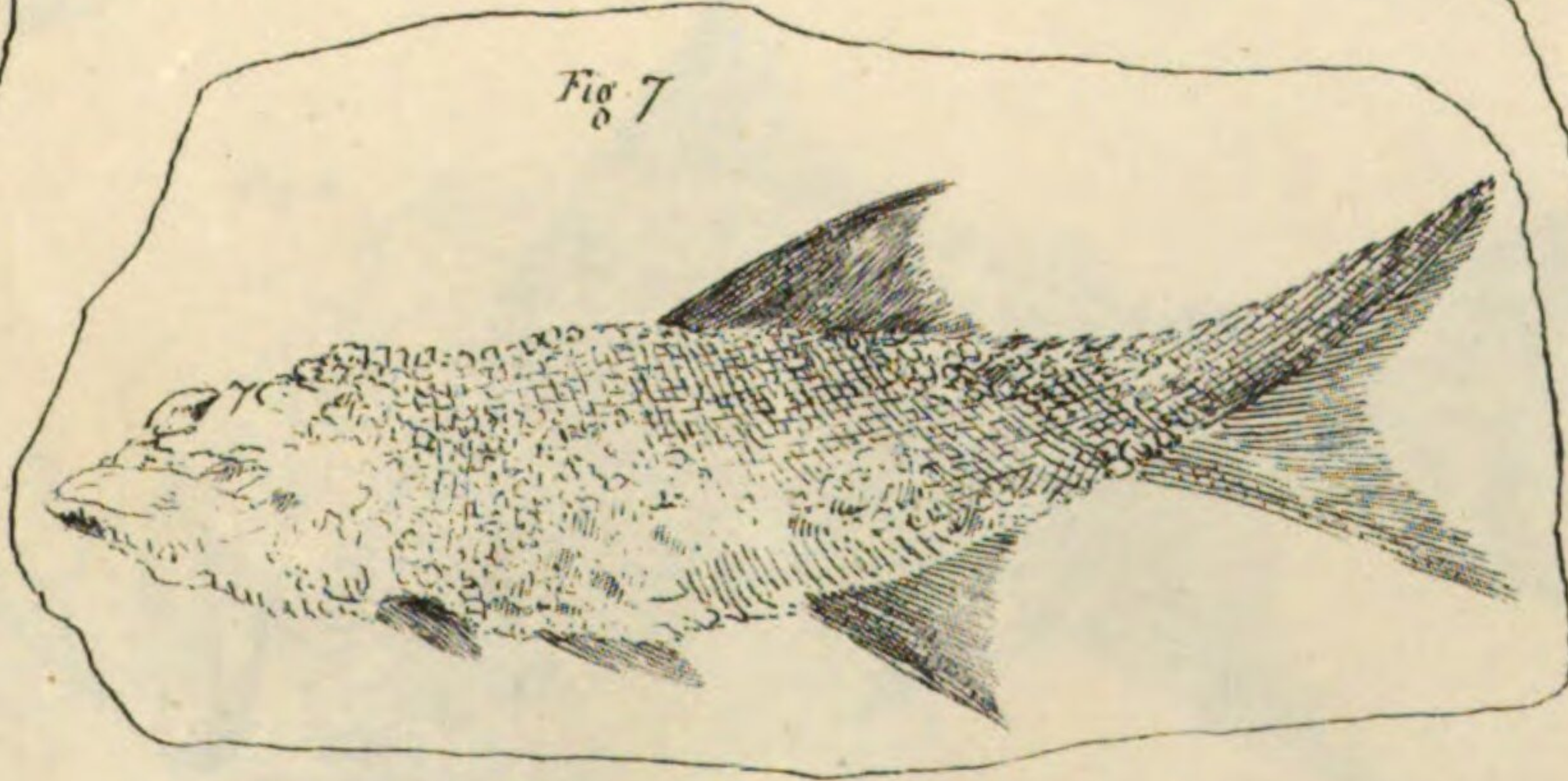
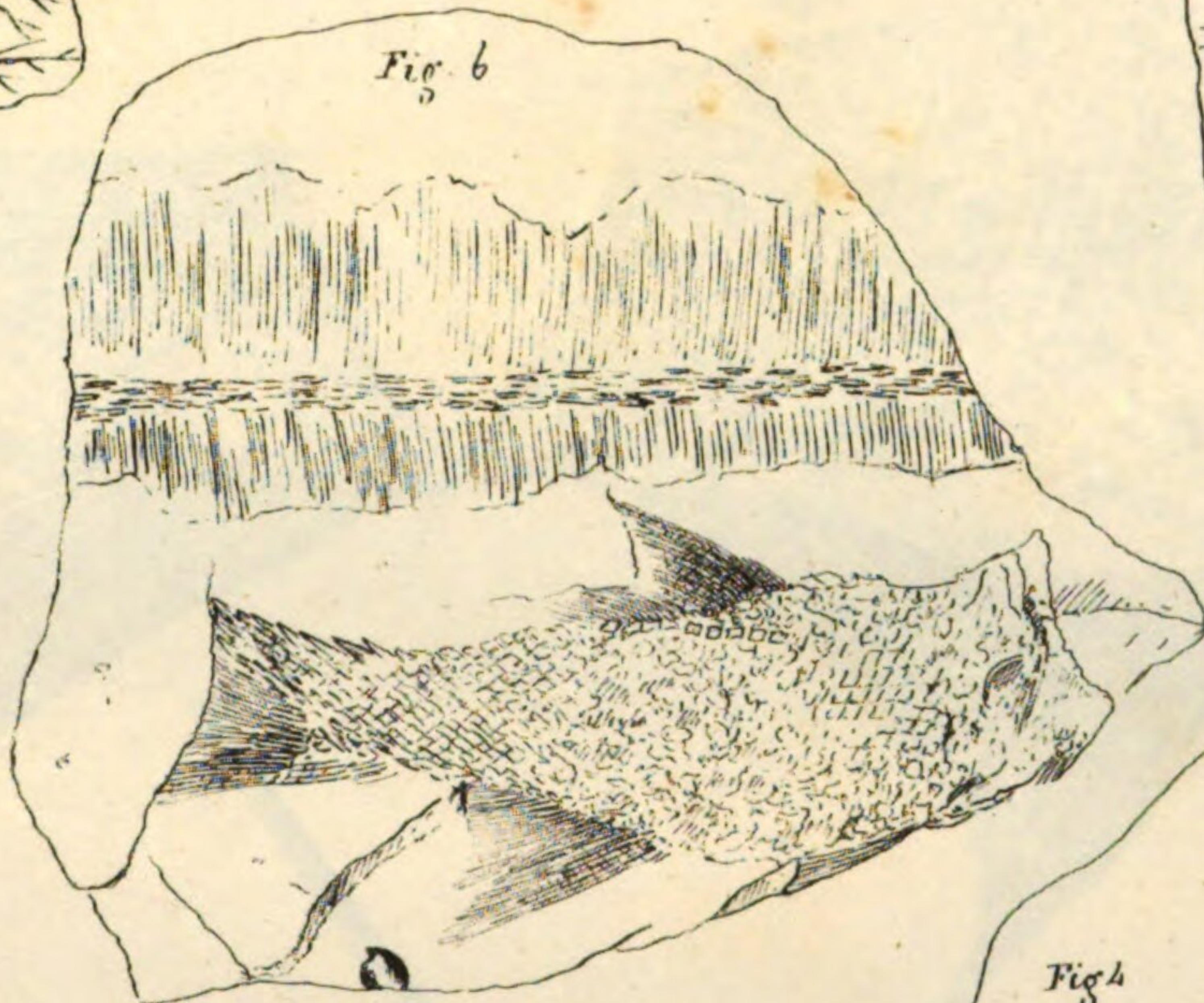
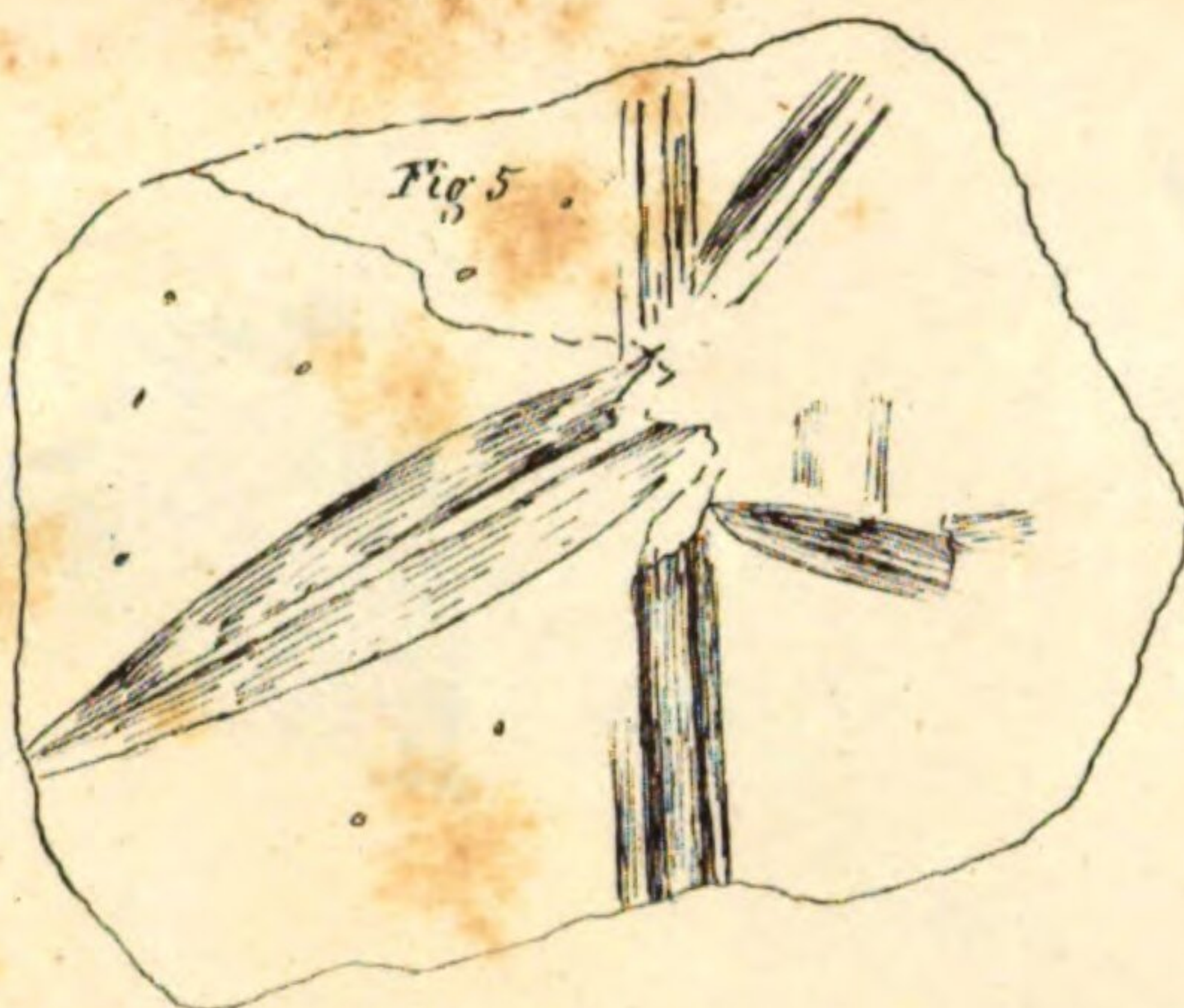
- Plate V. View of the old quarry of Burdiehouse. Described in Part I. section 17
- VI. The fossil plants described in Part I. section 3.
- VII. The lesser fish. Described in Part I. sections 7. and 13.
- VIII. The sauroid remains first discovered in the limestone. Described in Part I. sections 7. and 11.
- IX. The large fossil teeth. Described in Part I. sections 7. and 11.
- X. Part of the jaw and round scales of the *Megalichthys*. Described in Part I. section 11.
- XI. The scales of the *Megalichthys*, and the dorsal rays of the *Gyracanthus*. Described in Part I. sections 7, 11. and 14.
- XII. Specimens of the *Eurypterus* of Kirkton, &c. Described in the Supplement.



S. Hibbert Del^t

Printed by J & W. Smith, lithog.

The Sphenopteris affinis of Burdickhouse



Drawn by Mr. Hibbert.

Printed by J. & W. Smith, Lithog.

Specimens of the Freshwater Limestone of Breddie House.

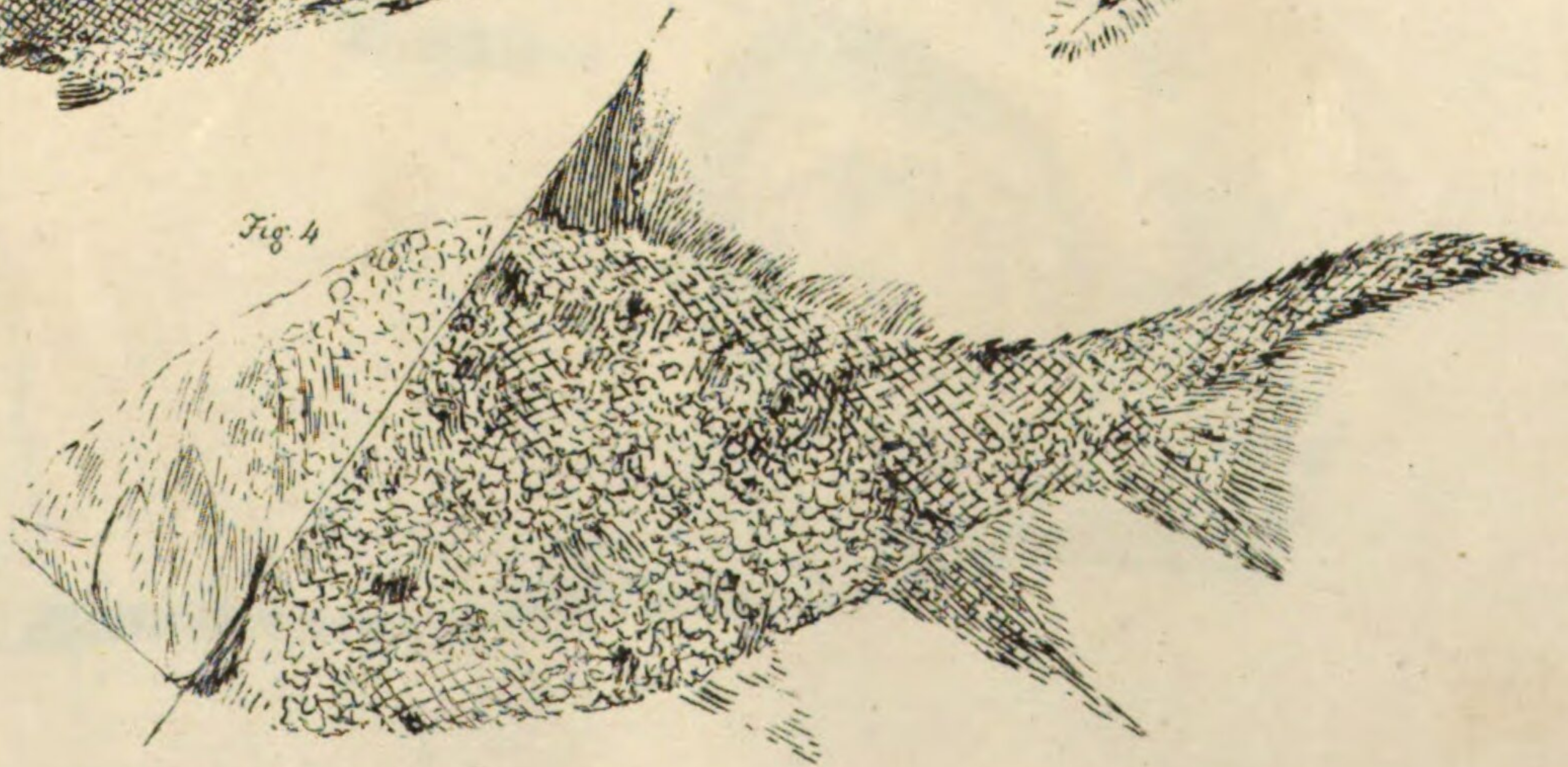
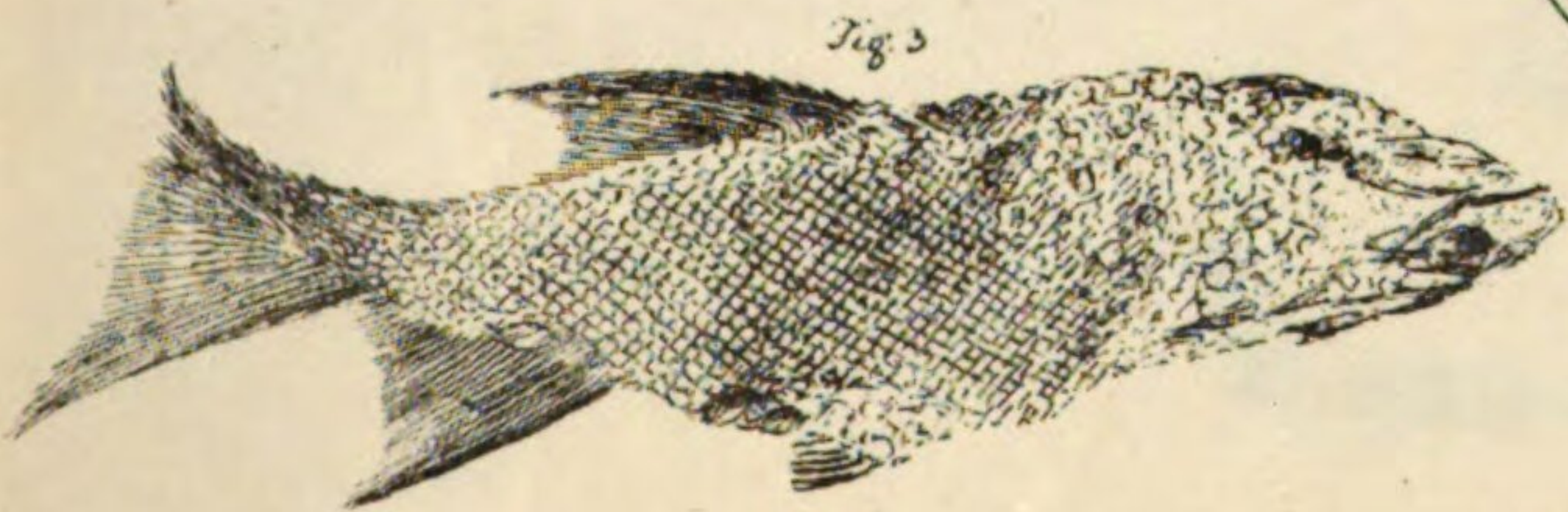
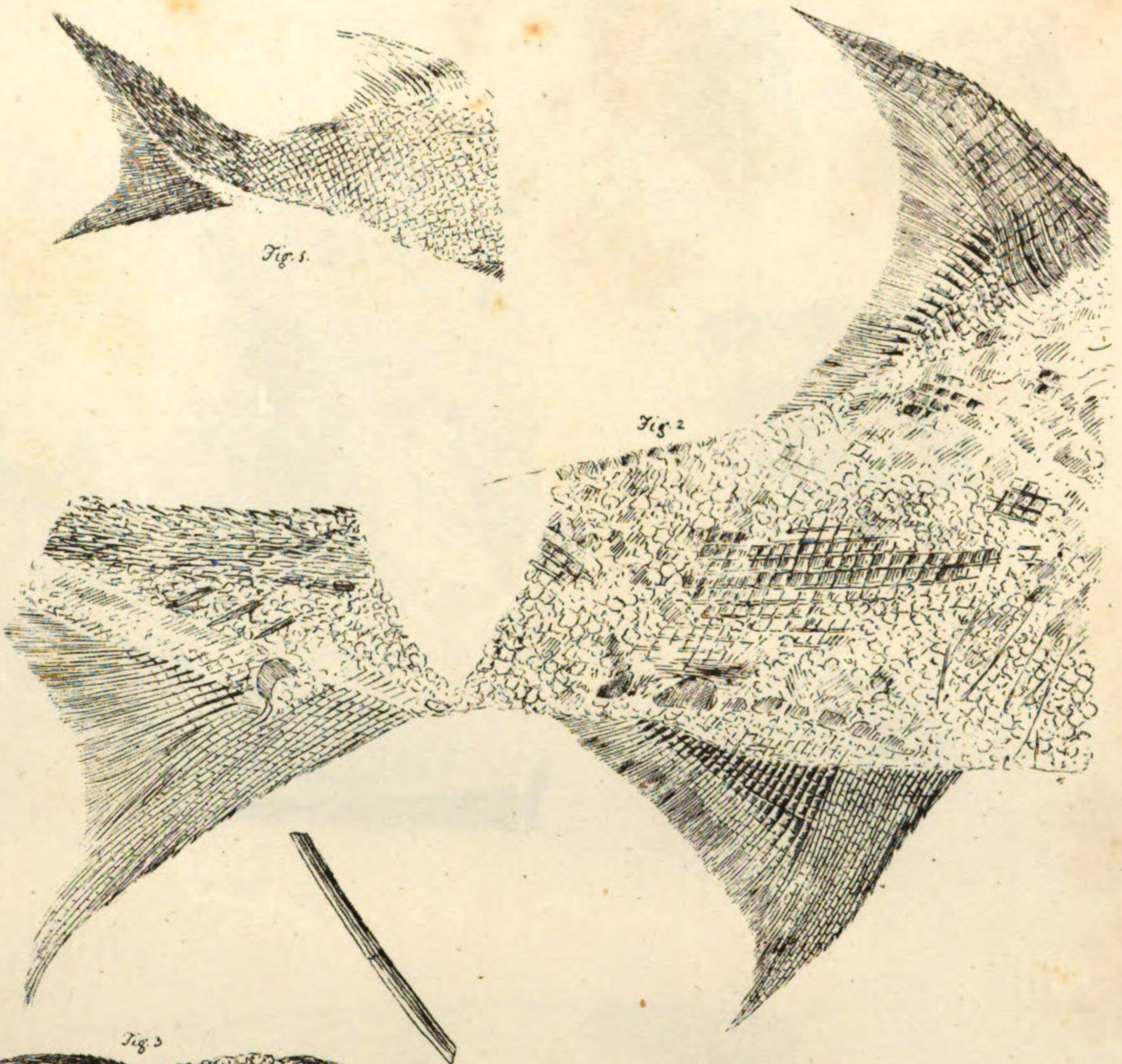
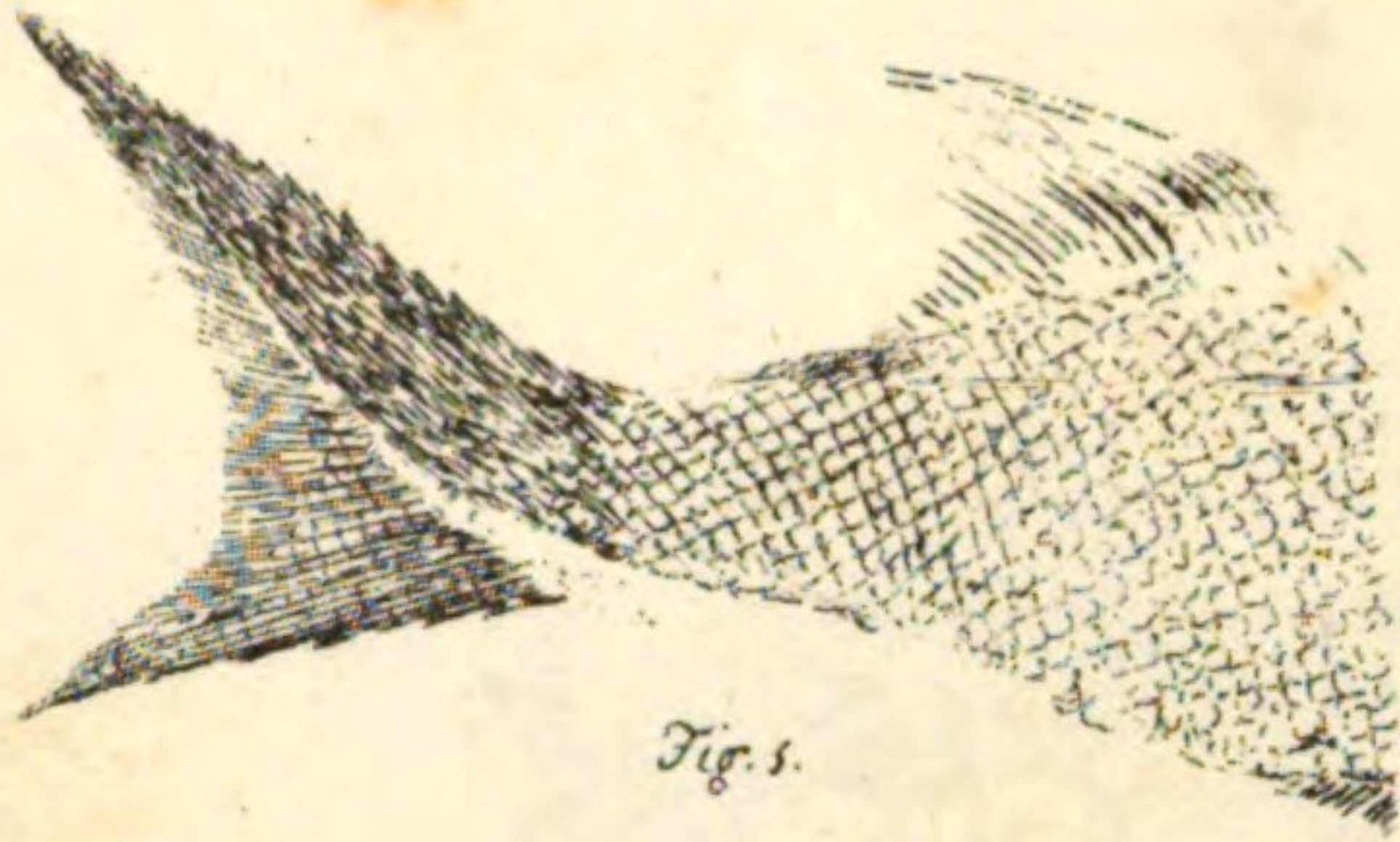
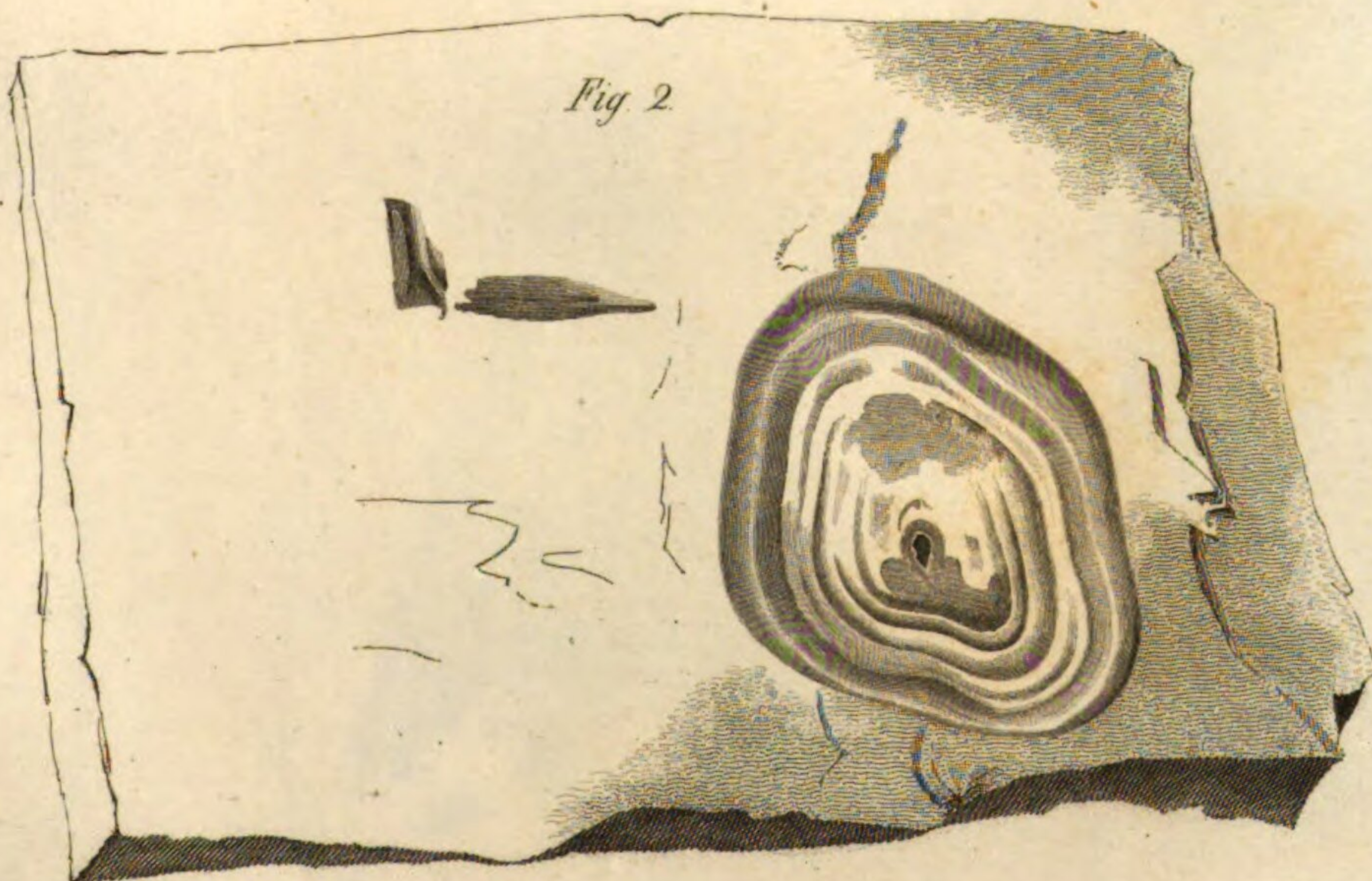
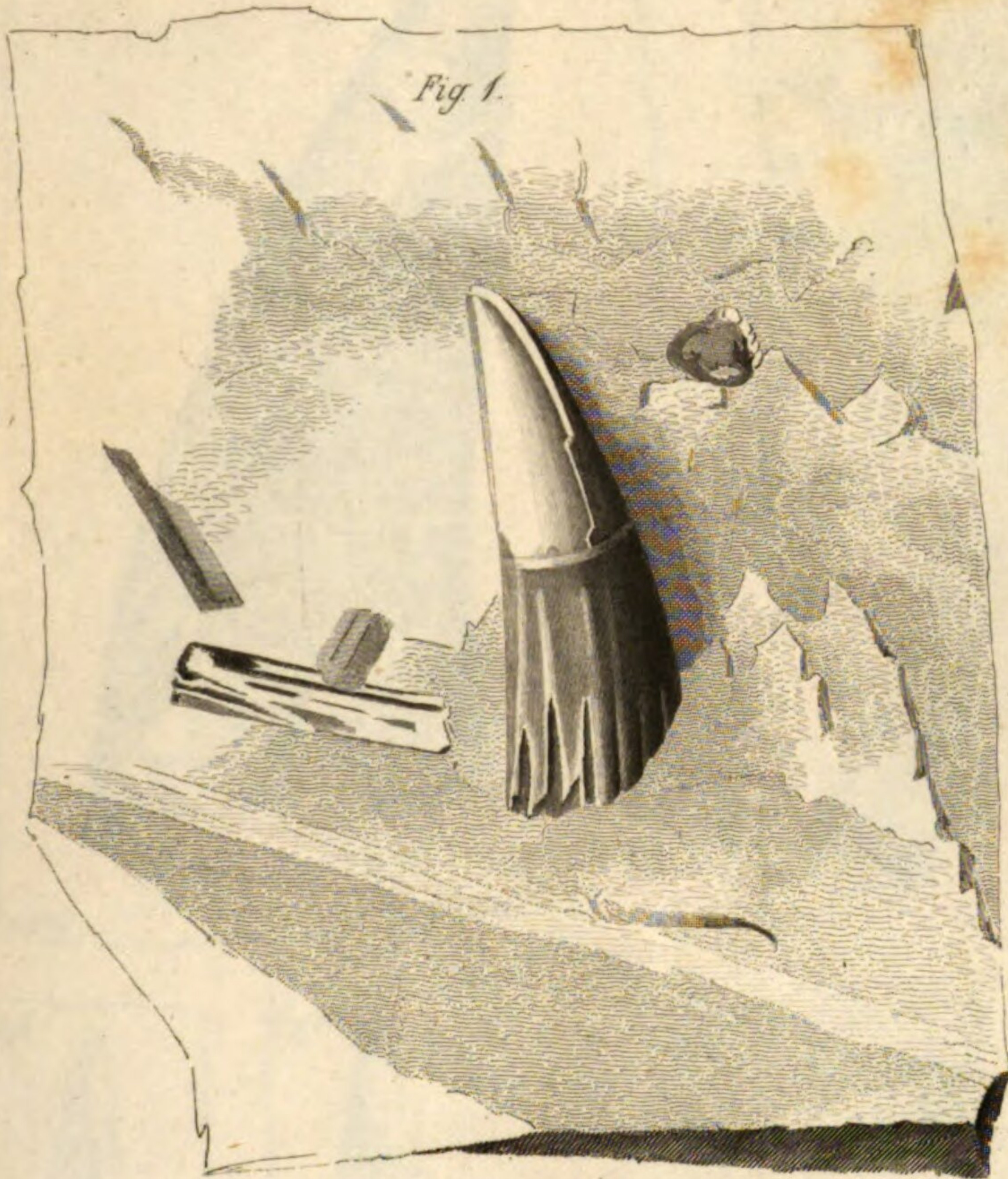
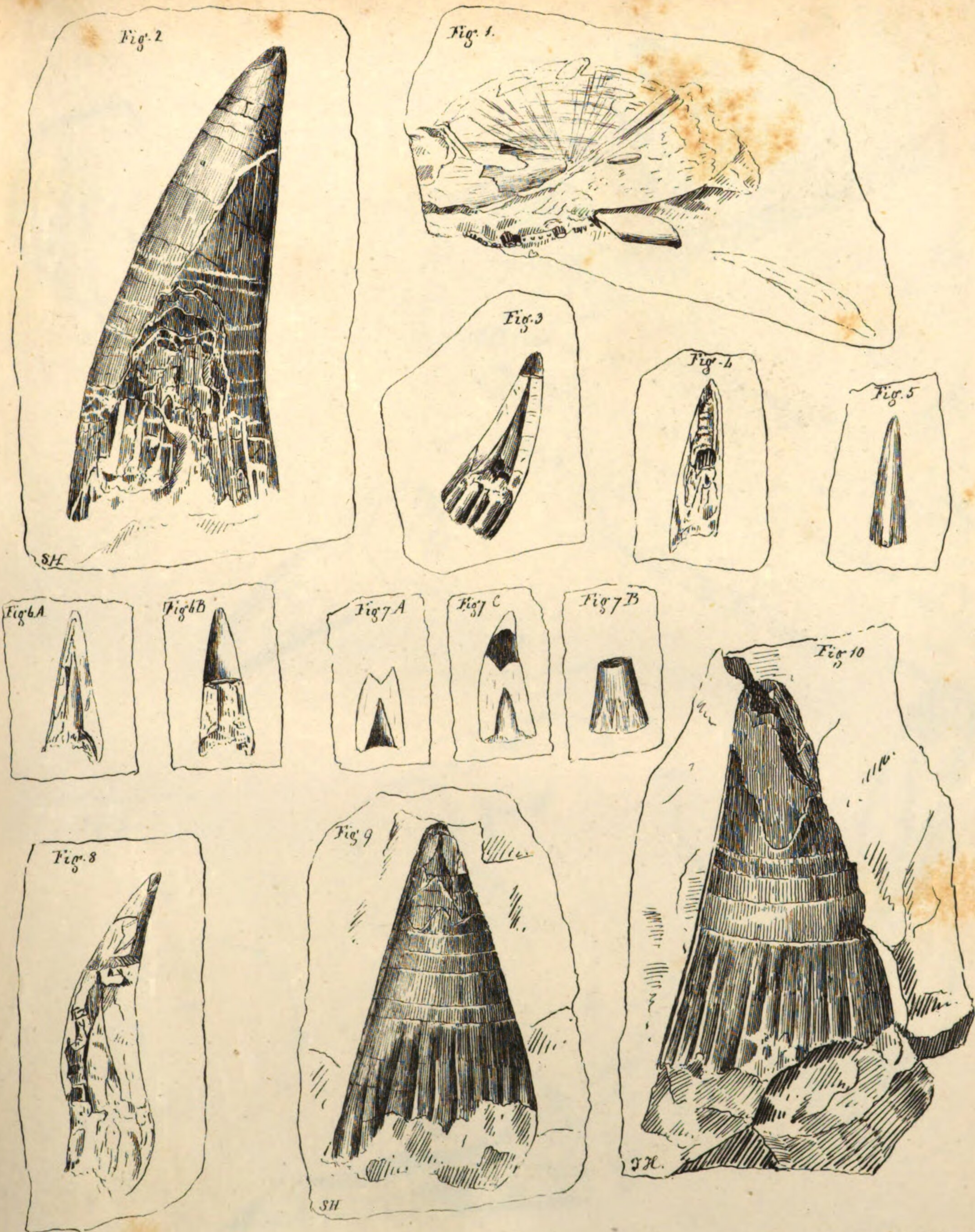


PLATE VIII.





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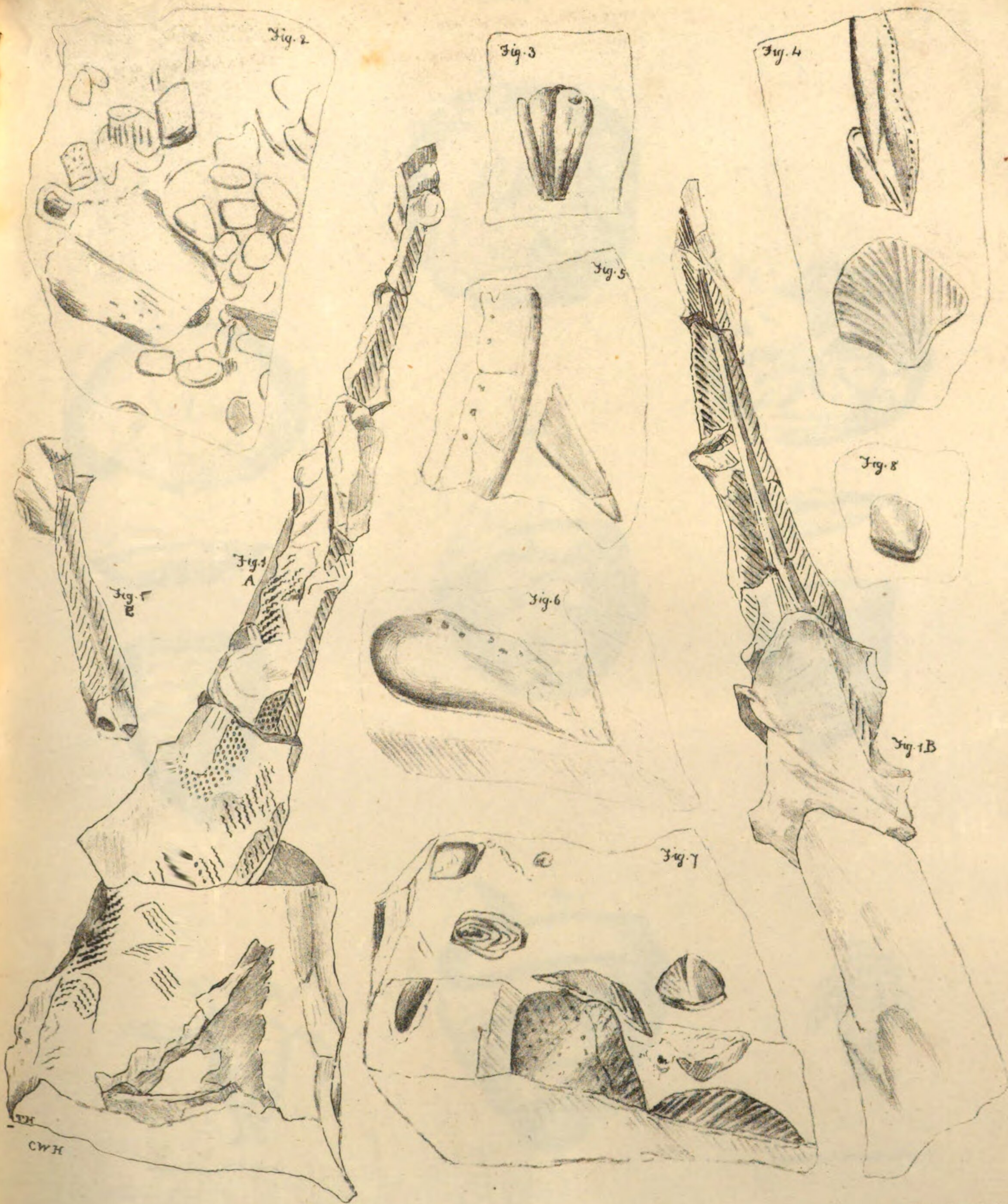
Fossil Teeth of the Brexide House Limestone.
Natural size.



Drawn by Mr. Herbert.

Printed by J. & W. Smith, Lithog^{rs}.

Osseous remains from the Limestone of Burdie House.
Natural size.



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Dorsal Ray [size] and Scales [natural size] from the Burdick House Limestone.

Fig. 3

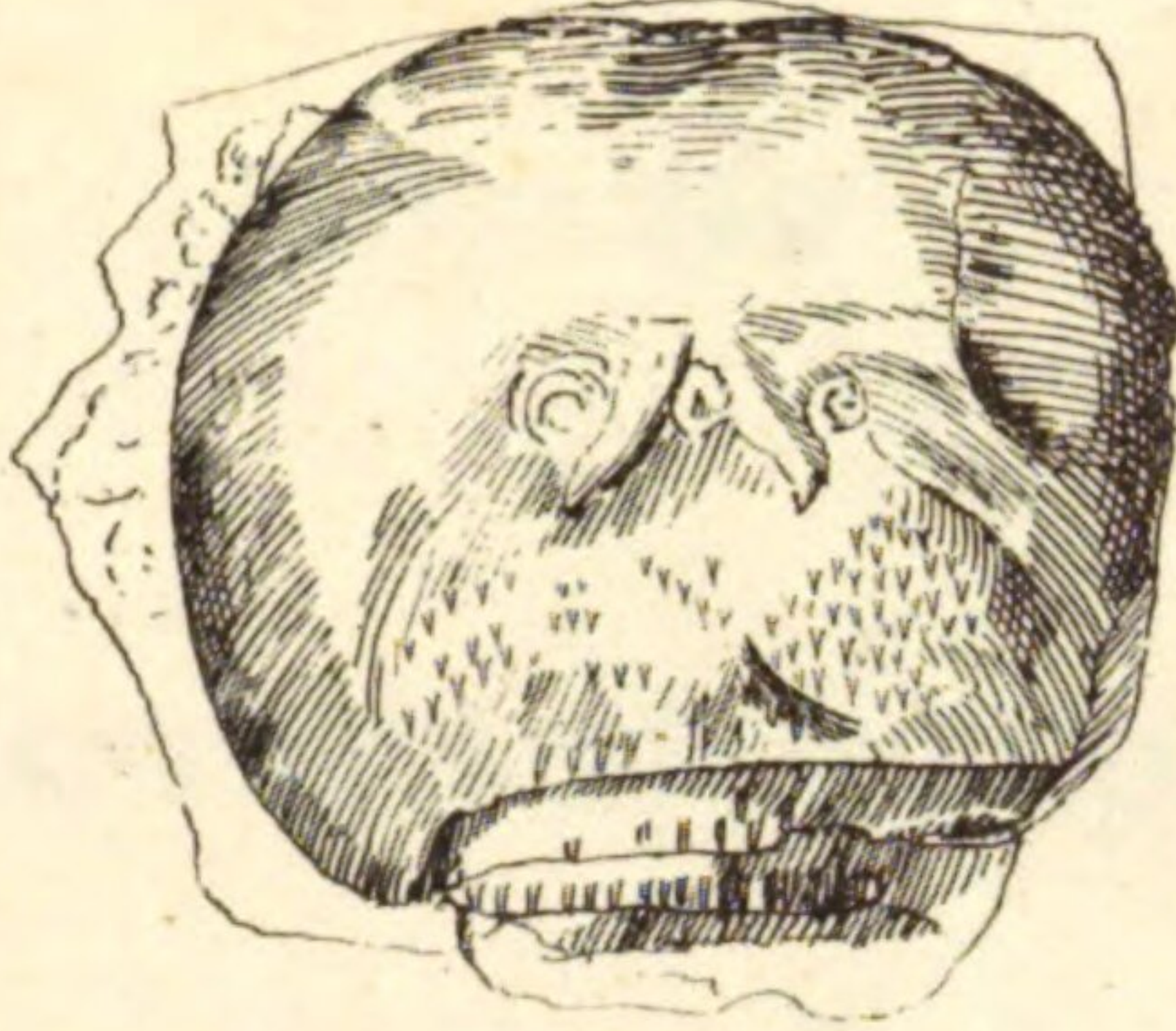


Fig. 2

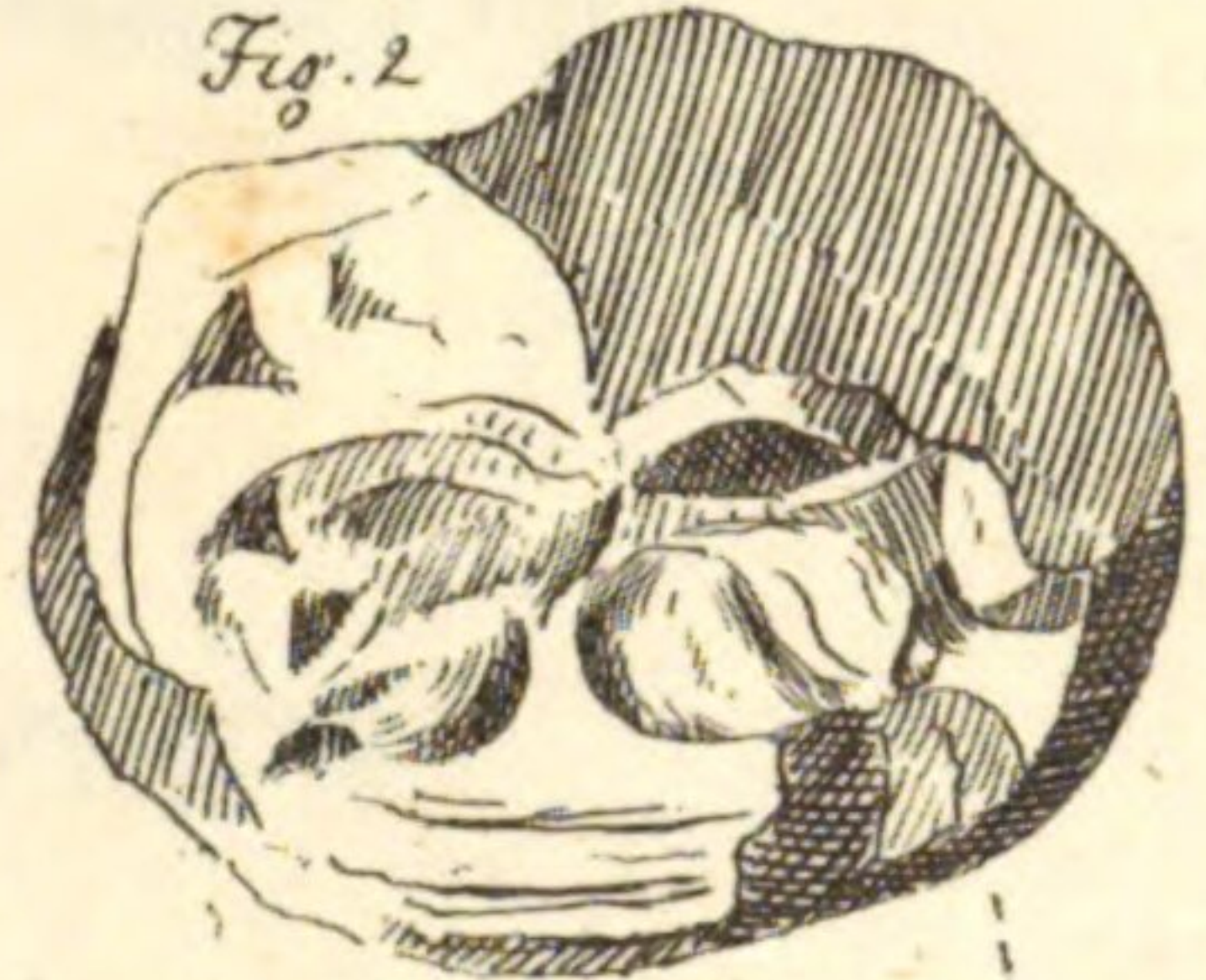


Fig. 4

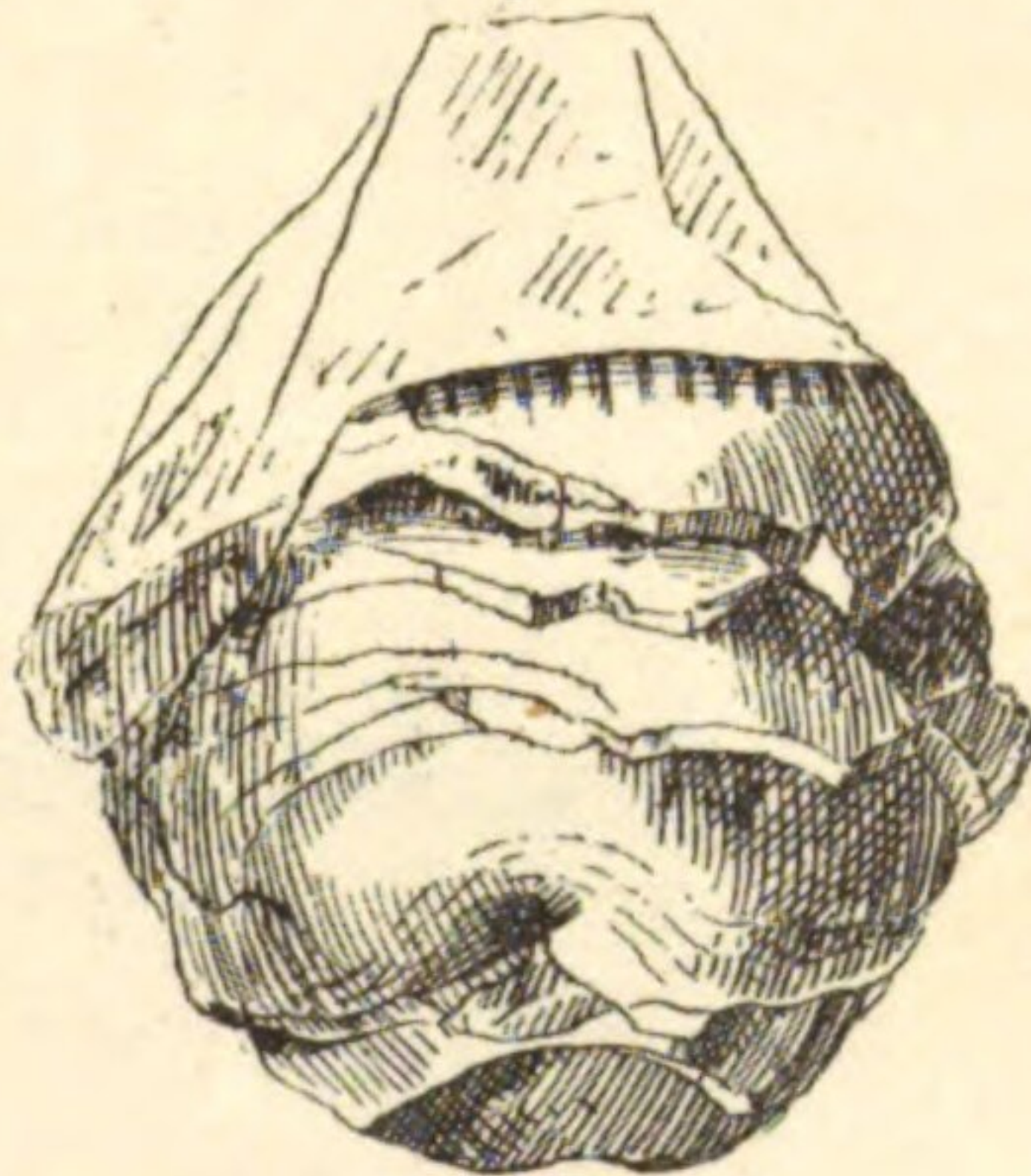


Fig. 1

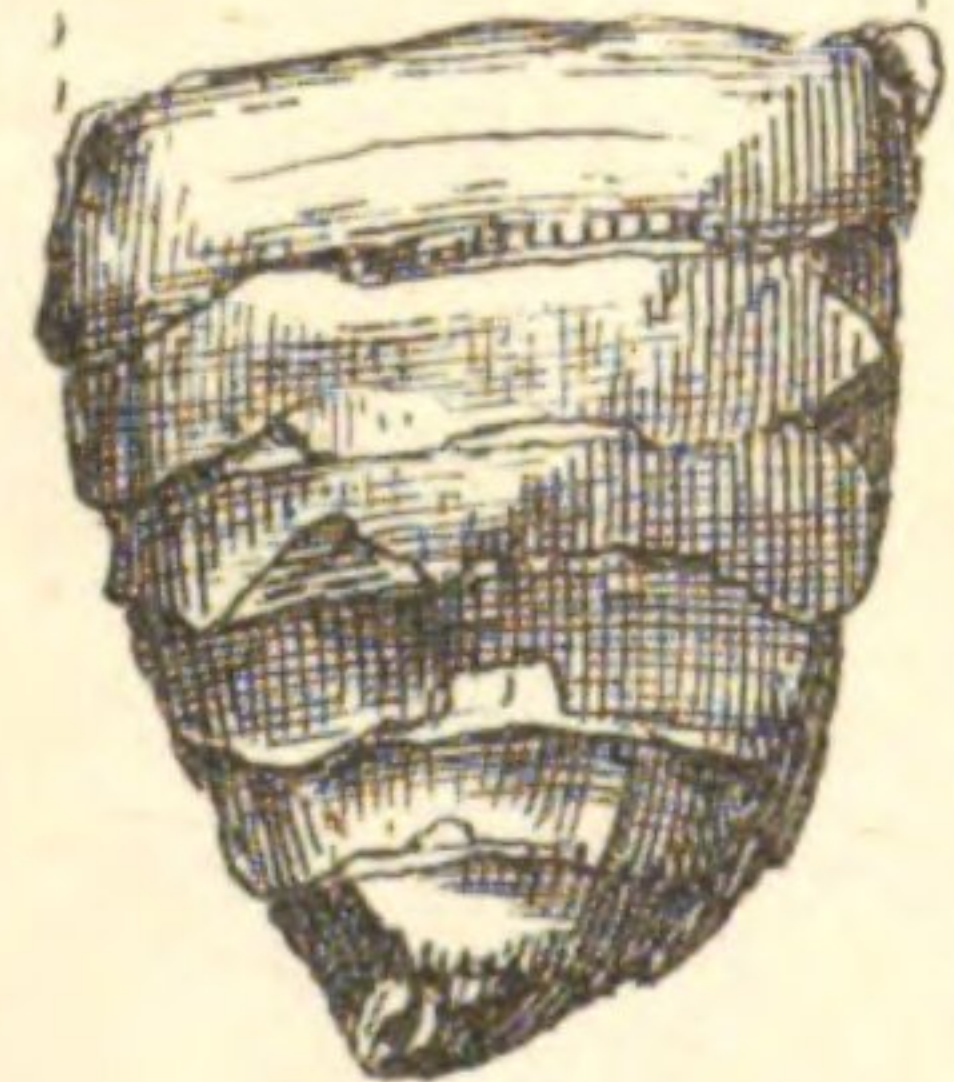


Fig. 5

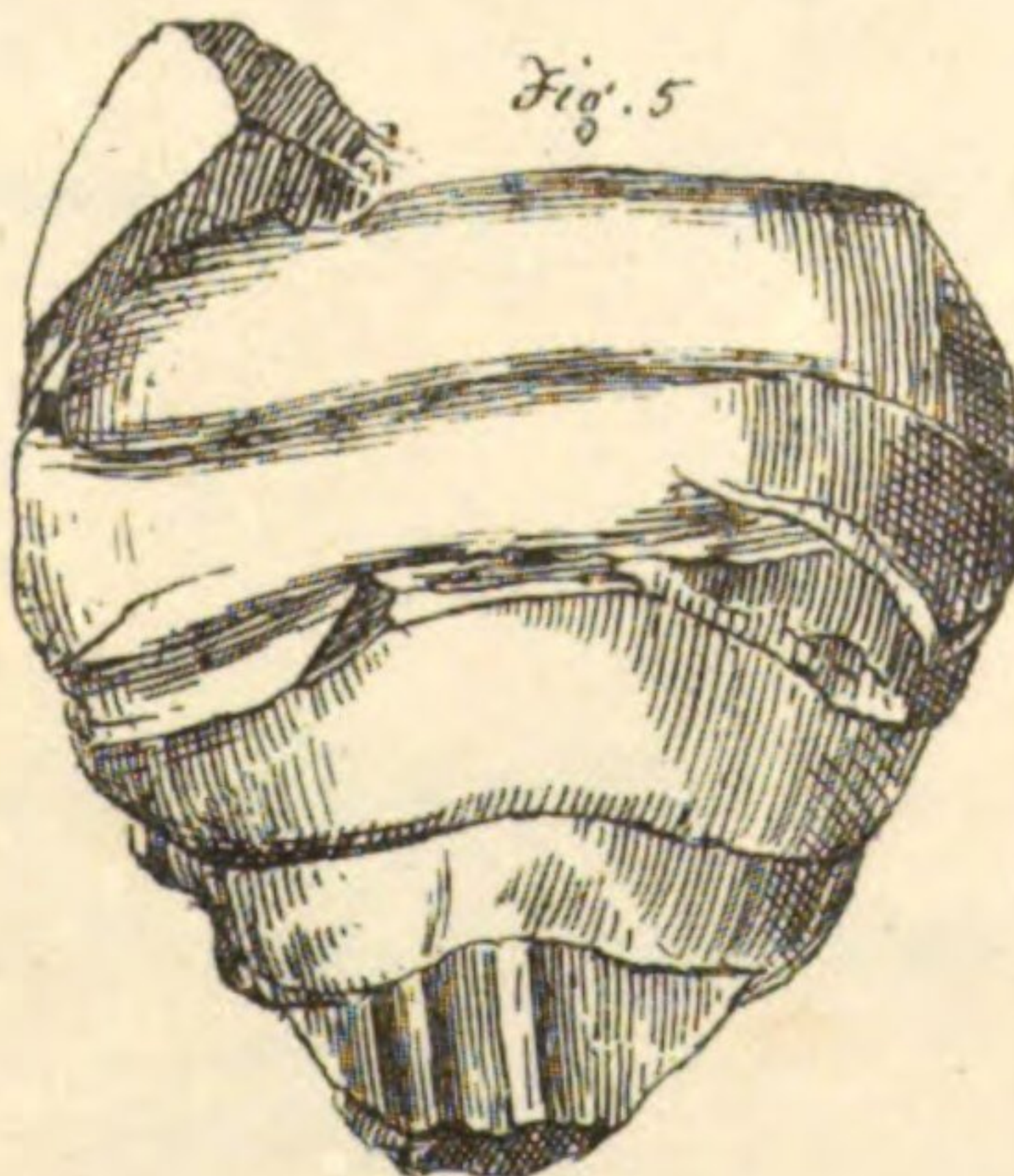
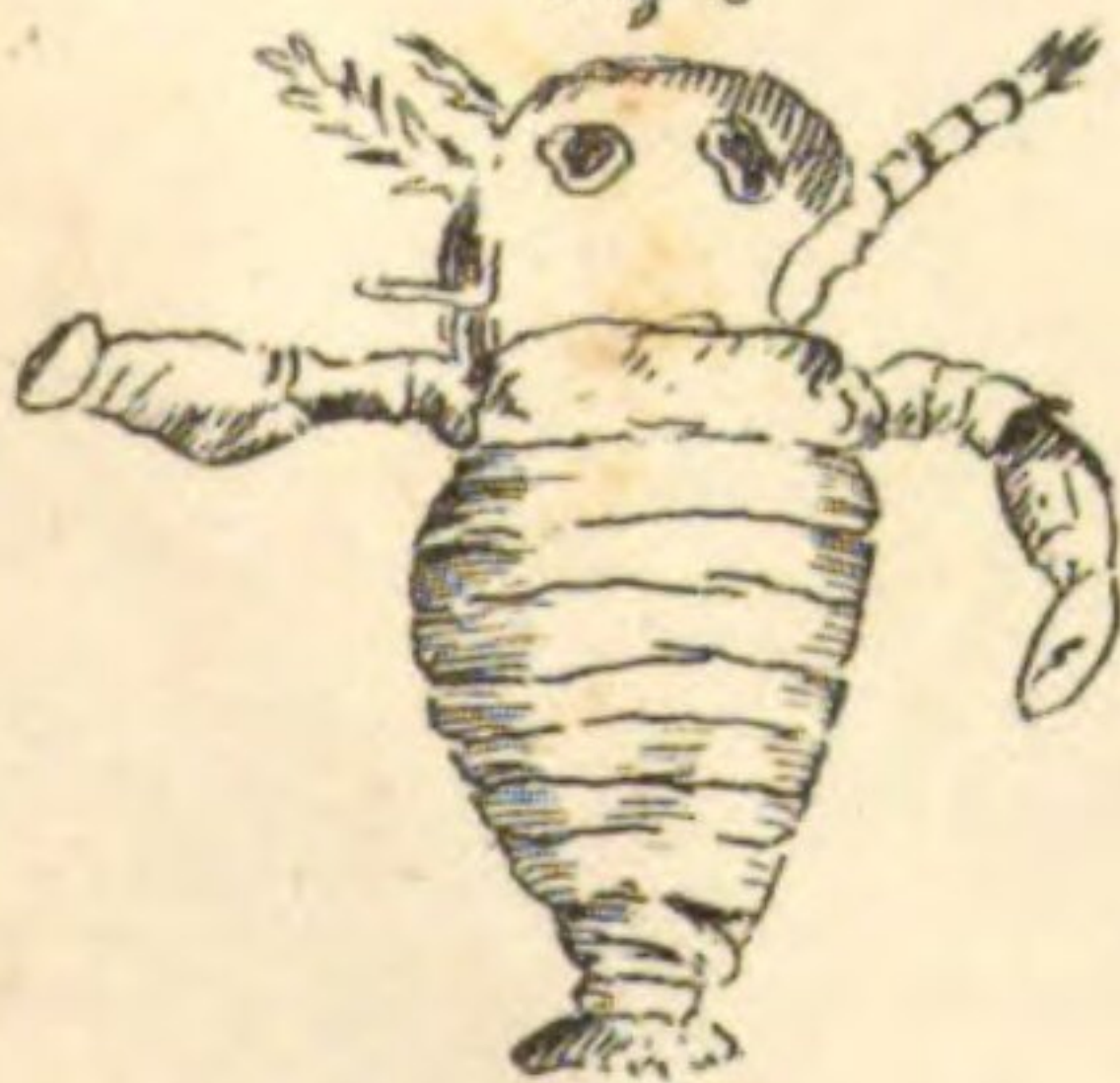


Fig. 6



Drawn by W. Hibbert

Fig. 7



Printed by J. & W. Smith, lithog.

Remains of the *Eurypterus*. $\frac{1}{4}$ Size.

ANALYSIS
OF
COPROLITES AND OTHER ORGANIC REMAINS
IMBEDDED IN THE
LIMESTONE OF BURDIEHOUSE, NEAR EDINBURGH.

ARTHUR CONNELL, Esq. F. R. S. E.

From the **TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH,**
VOL. XIII.

(Read 17th February 1834, and 19th January 1835.)

EDINBURGH:
PRINTED BY NEILL & COMPANY.

MDCCCXXXV.

ANALYSIS

OF

CORROSIONS AND OTHER ORGANIC REMAINS

IMBEDDED IN THE

LIMESTONE OF BURDIEHOUSE NEAR EDINBURGH.

It is expected that **AUTHORS** who receive separate Copies of their
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ARTHUR CONNELL, Esq. F.R.S.E.

By Order of the Council,

JOHN ROBISON, Sec.

FROM THE TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH.

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ANALYSIS OF COPROLITES AND OTHER ORGANIC REMAINS.

It is not my intention to enter into any detailed description of the external characters of the several interesting organic remains which are found imbedded in the limestone of Burdighouse, that being a task which belongs to their distinguished discoverer Dr HIBBERT.

As little do I mean to describe the geological relations of the limestone bed, that being equally the province of Dr HIBBERT. It will be sufficient to state generally, that it forms one of the lowest members of the carboniferous group, being inferior in position even to the Encrinal mountain limestone of its immediate vicinity; and that besides its numerous animal remains, some of which will be mentioned in the sequel, it contains throughout its entire mass numerous impressions of land and fresh-water tropical plants.

The chemical constitution of certain of the animal remains is the subject which I have humbly undertaken to investigate. I shall first advert to the coprolites which are found in vast numbers imbedded in the limestone.

All the specimens of coprolites examined, appear to agree in the following general chemical characters.

When heated in a glass tube in the state of powder, they give moisture and bituminous oil; and test paper held in the tube

shews the presence of a trace of ammonia. This reaction indicates the existence of a minute quantity of animal matter; and it is proper to observe, as I shall afterwards have occasion to notice more particularly, that the dark coloured limestone itself, in which the coprolites are imbedded, shews a similar reaction. The coprolites are soluble in dilute muriatic acid with moderate effervescence, leaving a residue of dark flocky matter; and when the solution is treated with ammonia, a plentiful gelatinous precipitate is thrown down, having all the appearance of phosphate of lime. Examined in the usual way for detecting phosphoric acid by means of potassium, they afford very decided indications of the presence of that acid. They also contain a little oxide of iron, but no sulphur in any state of combination. Magnesia was sought for both by fusion with carbonated alkalies and other necessary steps, in which way none was detected; and also by BERZELIUS'S process for finding it in bones.* The ultimate ignited residue got by this latter method consisted almost entirely of siliceous and alkaline matter, with only a very minute quantity of magnesia. A trace of fluoride of calcium is easily detected by treating the coprolites with sulphuric acid in the usual way.† Phosphate of lime and carbonate of lime are thus the prevailing constituents.

I next proceeded to ascertain the proportion of these constituents; and, as it is stated by Dr PROUT in his analysis of the coprolites from the lias, that the proportions appeared to differ not merely in different specimens, but in different parts of the same

* Lehrbuch, iv. 445.

† In my first search for fluoric acid I merely employed the blowpipe test of fused salt of phosphorus and Brazil wood paper, with the delicacy of which, the alkaline reaction of the coprolites interfered. In the mean time, Dr GREGORY and Mr WALKER found fluoric acid, in the usual way, in a coprolite examined by them; and I have since found that, with due precaution, it may be detected even by the blowpipe test.

specimen, I wished to ascertain how far a similar variation might be observable in the present instance.

In selecting specimens for a fuller analysis, it appeared to me to be desirable, on the one hand, that such coprolites should be chosen as contained fish scales, because it is by such contents as these that the real nature of these fecal remains is best evinced; and, on the other hand, that the quantity of these contained remains should not be greater than was sufficient to afford decisive evidence of their presence, because the purity of the proper matter of which the coprolites consist would be in some measure affected by them. Two specimens were chosen, in one of which the imbedded coprolite was about 2 inches long by 1 inch broad, and in the other it was about $2\frac{1}{2}$ inches by $\frac{3}{4}$ broad. The colour of both was yellowish-white. Their texture was compact, with a conchoidal fracture. A few fish scales were scattered through their substance. 22.99 grains of the former coprolite were dissolved in diluted muriatic acid, and the loss of weight resulting from effervescence ascertained to be 1.07 grains. A good deal of brown flocky matter was left, which was separated by filtration, and dried at the temperature of 212° , when it weighed 1 grain. It then appeared as a black coally mass, which fused on the application of heat, gave a white inflammable vapour and took fire, and burned with flame, leaving a residue of silica amounting to .09 of a grain. This, in short, was bituminous matter, which, as will presently appear, had been derived from the limestone. The muriatic solution was then precipitated by ammonia, in a little excess, and the phosphate of lime collected by filtration, and ignited. It then weighed 19.56 grains. The remaining liquid was precipitated by oxalate of ammonia, and after calcining the precipitate under the usual precautions, 2.48 grains of carbonate of lime were procured, which contain 1.083 of carbonic acid, and thus correspond sufficiently with the loss of weight by effervescence.

We have thus in 22.99 grains,

Phosphate of Lime, with a little fluoride of calcium,	19.56
Carbonate of Lime,	2.48
Silica,	.09
Bituminous Matter,	.91
	23.04

In this analysis alkaline matter in the residual liquid was not sought for ; but another portion of the same coprolite was decomposed for that purpose by muriatic acid, and after getting quit of the earthy constituents, a small residue of chlorides of potassium and sodium was got, amounting to .59 per cent. of alkalies, which probably were combined, in the matter under analysis, with siliceous matter, as chlorine or sulphuric acid were not detected in the coprolites.

The constituents in 100 parts were thus,

Phosphate of Lime, with a little fluoride of calcium,	85.08
Carbonate of Lime,	10.78
Phosphate of Magnesia,	Trace
Silica,	.39
Potash and Soda,	.59
Bituminous Matter,	3.95
Animal Matter,	Trace
	100.79

13.76 grains of the other coprolite were decomposed by the same process, the only difference being that the loss of weight by effervescence was not determined, and that the amount of the bituminous and alkaline matter was merely estimated from the deficiency on the analysis. This coprolite contained in 100 parts,

Phosphate of Lime, with a little fluoride of calcium,	83.13
Carbonate of Lime,	15.11
Phosphate of Magnesia,	Trace
Silica,	.29
Animal Matter,	Trace
Bituminous Matter and Alkalies,	1.47
	100.

A portion from a different part of this coprolite yielded 84.17 per cent. of phosphate of lime.

It thus appears that the proportion of phosphate of lime, the principal constituent of these remains, is pretty uniform, in so far as the examination extended. A little variation occurs in the relative quantity of the other constituents. Of these last, the bituminous matter is certainly derived from the matrix; and it seems probable that the proportion of the carbonate of lime is also slightly influenced by the limestone, as I shall afterwards have occasion to shew. The proportion of phosphate of lime is much greater than in the lias coprolites, in which it appeared to vary, according to Dr PROUT, from only $\frac{1}{4}$ th to $\frac{5}{4}$ ths of the whole; whereas in those of Burdiehouse it amounts to about $\frac{5}{6}$ ths*.

On finding the bituminous matter in the coprolites, I subjected the limestone to the same process, to separate the bitumen from it. A portion of the limestone matrix of the coprolite first analyzed was dissolved in diluted muriatic acid, and the undissolved dark flocky matter collected on a filter, washed, and dried at the temperature of 212° . It then contained one-half of earthy matter, and hence was not so black and glossy as that from the coprolites, nor did it fuse on the application of heat; but, when heated in the open air with the contact of flame, it took fire and burned with flame; and, when heated in a

* With reference to an analysis lately published by Dr GREGORY and Mr WALKER, (Edin. New Phil. Jour., Jan. 1835,) of a coprolite described as embedded in a rolled mass of clay-iron from Burdiehouse, it is necessary to observe, that this coprolite appears to have been extremely impure, containing only 10 per cent. of phosphate of lime, and much foreign matter, such as sulphuret of iron, and large quantities of carbonates of lime and magnesia. It is essential, therefore, to draw a marked line of distinction between coprolites in ironstone or shale, and those directly embedded in the limestone of Burdiehouse, to which last alone my analyses refer. I have seen coprolites from the shale of Burdiehouse, but I have never happened to see any from that locality, either in ironstone or in rolled masses.

tube, a yellow oil was sublimed, with a strong bituminous odour, and the oil concreted on cooling,—appearances which are also presented when the bituminous matter from the coprolites is treated in the same manner. The quantity of bitumen obtained from the limestone, after subtracting the earthy matter, was about $2\frac{1}{2}$ per cent.; but the proportion may vary in different specimens. The bitumen might also be obtained by distillation; for when the powdered limestone is heated to redness in a glass tube, a brown oily liquid is volatilized, which concretes on cooling.

It may also be worth while to notice, that the matter composing the carbonaceous layers, covering many of the fine vegetable impressions of the limestone, possesses, in its relations to heat, all the properties of common black coal; and appears, in many instances, to be all that remains of those vegetables which have left their impressions on the matrix. Thus these miniature beds of coal afford an excellent illustration of the origin of their more gigantic likenesses in the coal-measures.

The next fossils from the limestone which I submitted to analysis, were a portion of a bony fin ray, sent to me for that purpose by Dr HIBBERT; and also some scales obtained from the collection of the Royal Society.

Both these substances, as may well be supposed from their great antiquity, afford only slight traces of perishable animal matter. At a red heat, they give off a little water and ammoniacal vapour; and a slightly empyreumatic odour is also evolved, arising from a small quantity of bituminous matter contained in them. The alkaline reaction, however, particularly that of the bones, is not so decided as that of the coprolites or limestone matrix itself.

The details of the method of analysis need not be entered into, as the general nature of the process employed was the same as that used in the analysis of the coprolites.

The bony fin rays, Dr HIBBERT informs me, belong to a fossil fish, which has been designated by M. AGASSIZ, *Gyracanthus formosus*, and is supposed to approach in character to the *Cestracion* of New Holland.

20.14 grains of these rays were found to be composed as follows :

Phosphate of Lime, with a little Fluoride of Calcium,	53.87
Carbonate of Lime,	33.86
Siliceous Matter,	10.22
Potash and Soda, partly as Chlorides,	.71
Bituminous Matter,	.54
Phosphate of Magnesia,	Trace
Animal Matter,	Trace
	99.20

The siliceous matter contained in the fin rays was left undissolved when they were treated with the acid, and presented the appearance of small solid cylindrical masses, grouped longitudinally together. These siliceous portions may be observed in the solid bone itself, before it is acted on by the solvent, and evidently suggest the idea of longitudinal cavities in its substance, which had become filled with infiltrated siliceous matter.

The scales analyzed were those of the fossil genus of fish to which the name of *Megalichthys* has been given by M. AGASSIZ. The great fossil teeth found at Burdiehouse belong to the same animal. It is supposed to approach in its characters to the *Lepisosteus*, or *Lepidosteus* of AGASSIZ. The scales had the usual fine lustre, and smooth but delicately punctured surface. They were generally about three-fourths of an inch long, by somewhat less in breadth.

15.86 grains of these scales submitted to analysis gave the following result :

Phosphate of Lime, with a little Fluoride of Calcium,	50.94	
Carbonate of Lime,	11.91	
Siliceous matter,	33.10	} 36.58
Water,	3.48	
Potash and Soda,	.47	
Bituminous Matter,	.12	
Phosphate of Magnesia,	Trace	
Animal Matter,	Trace	
	100.02	

The most unexpected part of this analysis was the occurrence of so large a proportion of siliceous matter. Judging from the beautifully perfect appearance of these scales, presenting a lustre as fine in all likelihood as they possessed when they clothed the sides of the immense living tenants of the primeval waters, we are naturally led to expect no great change in their nature. A little reflection, however, will show us that as fish scales are known to contain a good deal of perishable animal matter, in addition to the more permanent animal earths, which enter into their composition, it is necessary that the place of this destructible matter should be taken by something more durable, in order that the original form may be preserved. This seems to be the origin of the siliceous matter; and, in proof of the justness of this view, it need only be mentioned, that when the scales are acted on by acids, the insoluble matter remains behind as a fine siliceous skeleton, formed, there can be little doubt, by the infiltration of dissolved siliceous matter which has gradually taken the place of the decaying animal matter. The fossil scales, on this view, ought to consist of the infiltrated matter, together with the original animal earths; and this is exactly what we find to be the case; and it so happens, that in the present instance we are enabled to determine, with some degree of plausibility, that even the relative proportions of the different constituents have been to a considerable extent preserved. We luckily possess an analysis of the scales of the recent *Lepisosteus*, as well as of several

other recent fishes, by CHEVREUL ; and, it is very interesting that, on comparing the analysis of the scales of the *Megalichthys* of Burdiehouse with those of the *Lepisosteus*, to which, on the high authority of M. AGASSIZ, the *Megalichthys* is in other respects allied, we find a considerable approximation between the proportions of the different constituents of the scales of the recent and of the fossil fish on substituting siliceous matter for destructible animal matter ;—not certainly a numerical identity, but still a marked analogy, and one of a much stronger description than between the fossil scales and those of the other recent fishes. CHEVREUL's analyses are as follows :*

	<i>Lepisosteus.</i>	<i>Perca labrax.</i>	<i>A Chætodon.</i>
Phosphate of Lime,	46.20	37.80	42
Carbonate of Lime,	10.00	3.06	3.68
Gelatinous Animal Matter,	41.10	55.	51.42
Phosphate of Magnesia,	2.2	.90	.90
Fatty Matter,	0.10	.40	1.
Carbonate of Soda,	0.10	.90	1.
	100.	98.06	100

On comparing the proportion of the first three of the above constituents with the corresponding ingredients in the fossil scales, we shall see the analogy, and it is somewhat increased by the circumstance, that the water was in combination with the siliceous matter, as I ascertained by igniting a portion of it after drying it at 212° ; so that in reality both these constituents, forming together a hydrated siliceous matter, have been substituted by infiltration for the animal matter.

We may recall to remembrance, that the limestone matrix contains about $2\frac{1}{2}$ per cent. of earthy matter, so that we can be at no loss to account for the occurrence of the siliceous matter.

The following comparison, framed on this view, will show the

* BERZELIUS, *Lehrb.* iv. 628.

resemblance in composition between the recent and the fossil scales.

	Scales, Lepisosteus.	Scales, Megalichthys.
Phosphate of Lime,	46.20	50.94
Carbonate of Lime,	10.	11.91
Animal Matter replaced in the Megalichthys by Hydrated Siliceous Matter,	41.10	36.58
Phosphate of Magnesia and Alkalies, small quantities.		
	97.3	99.43

I am happy in being able thus to add something like chemical evidence in support of the alliance between the sauroid fish of Burdiehouse and its supposed living type.

I have found also that the scales adhering to coal discovered by Lord GREENOCK at Craighall, and of which his Lordship was so kind as to give me some specimens for chemical examination, leave, when acted on by acids, a siliceous skeleton, which doubtless has been supplied by substitution for animal matter in the same manner as in the other, although to a less extent. I have not yet had time to complete an analysis of these scales, but shall communicate the result to the Society when obtained. I hope to be able to communicate at the same time some other analyses, farther illustrative of the question how far the chemical nature of fossil scales may be capable of throwing light on the character of the animals from which they have been derived.

It is worthy of remark, that the manner in which the animal matter of the scales of the Megalichthys has been replaced by siliceous matter, is very conformable to that in which, according to the views of VON BUCH, shells have in certain instances been silicefied. According to that eminent geologist, it is only the animal matter between the calcareous layers of the shell which is converted into siliceous matter, the calcareous layers being usually thrown off altogether, although sometimes included within the flinty substance, but never themselves silicefied.

In like manner in the scales, the phosphate and carbonate of

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Phosphate of Magnesia,	2.2	.90	.90
Fatty Matter,	0.10	.40	1.
Carbonate of Soda,	0.10	.90	1.
	100.	98.06	100

On comparing the proportion of the first three of the above constituents with the corresponding ingredients in the fossil scales, we shall see the analogy, and it is somewhat increased by the circumstance, that the water was in combination with the siliceous matter, as I ascertained by igniting a portion of it after drying it at 212° ; so that in reality both these constituents, forming together a hydrated siliceous matter, have been substituted by infiltration for the animal matter.

We may recall to remembrance, that the limestone matrix contains about $2\frac{1}{2}$ per cent. of earthy matter, so that we can be at no loss to account for the occurrence of the siliceous matter.

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In like manner in the scales, the phosphate and carbonate of

lime are unchanged in their nature, whilst the animal matter has been converted into a hydrated siliceous substance. The mineralizing substance of the silicefied shells is often also a hydrated silica or opal.*

As we possess one or two analyses of recent fish bones, we are also enabled to institute a comparison between the result of these analyses and that of the fossil bony rays. The following are the constituents found by DUMENIL in the bones of the pike, and by CHEVREUL in those of the cod.†

	Pike.
Phosphate of Lime,	55.26
Carbonate of Lime,	6.16
Animal matter,	37.36
Traces of Soda, &c. and loss,	1.32
	100.00
	Cod.
Phosphate of Lime,	47.96
Carbonate of Lime,	5.50
Animal Matter and Moisture,	43.94
Phosphate of Magnesia,	2.
Soda Salt,	6.
	105.

The first circumstance that here strikes us, is, that the proportion of phosphate of lime is almost identical in the recent bones of the pike, and in those of the ancient *Gyracanthus* of Burdiehouse; and it is very remarkable, that if we suppose the animal matter in the fresh bones of the *Gyracanthus* to be replaced partly by siliceous and partly by calcareous matter,—a supposition sufficiently legitimate, because both these matters are present in the matrix, and both are soluble in water under favour-

* In examining, however, the insoluble siliceous matter of the scales by the blow-pipe, it appears not to be a quite pure hydrated silica, but probably to contain a small quantity of lime.

† BERZELIUS, *Lehrb.* iv. 448.

able circumstances,—we shall obtain a substance almost identical with the recent bones of the pike, and not differing much from those of the cod. In this view, if we subtract from the calcareous matter actually found in the fossil bones, a quantity equal to that in the pike bones, and add the remainder to the siliceous matter, we shall obtain the following comparison, shewing a singular resemblance.

	Bones. Pike.	Bony rays. Gyracanthus.
Phosphate of Lime,	55.26	53.87
Carbonate of Lime,	6.16	6.16
Animal Matter replaced in the Gyracanthus, by siliceous and calcareous matter,	37.36	37.92
Phosphate of Magnesia, and Alkalies, small quantities.		
	98.78	97.95

I am aware, that if we adopt these last views, we must hold either, 1st, That the bony rays did not belong to a cartilaginous fish, in which class I believe the Cestracion is ranked, for the bones of cartilaginous fishes contain no bone earth; or, 2d, That the fin spines of cartilaginous fishes have a different constitution from the other bones, a point which I do not know has been yet investigated.

Even when we view the composition of the coprolites imbedded in the limestone, in combination with that of the recent fish-bones, we get something approaching to a coincidence. In one of my analyses of these coprolites, the ratio of the phosphate of lime to the carbonate of lime was about 8 : 1, and this does not differ very much from that of those constituents in the recent fish-bones, according to the analyses of DUMENIL and CHEVREUL. In the other coprolite which I analyzed, there is, on this view, an excess of about 5 per cent. of carbonate of lime, which, of course, was derived from the matrix. The phosphate and carbonate of lime form almost the entire mass of the coprolites from the limestone, the only other constituent of consequence being 2 or 3 per cent. of bituminous matter.

It would therefore seem that the coprolites of the limestone actually contain less foreign matter, or are less altered from their original nature in so far as regards solid contents, than the bones or scales; and this fact admits, I think, of a ready explanation. When a solid compact body, possessing a structure such as a bone or scale, has been imbedded in any situation in which water, holding solid matter in solution, has access to it, we may expect that, in the lapse of time, the perishable animal matter which it contains will disappear, whilst the dissolved solid matter will be deposited, by infiltration, and occupy its place, the original solid structure, more especially when aided by the solid organic earths, forming a kind of frame-work, on which the deposition will take place. This is just the process by which ordinary petrifying springs convert organic objects into the substance held in solution. But fecal matter, being composed of the residue of digested food, and being destitute of structure or solidity, will not present such a frame-work. The perishable animal matter will simply decay, whilst its place will not be occupied by a substitute; the solid animal earths will simply agglomerate into a compact mass; and therefore we shall expect to find them,—what they really appear to be as imbedded in the limestone of Burdiehouse,—masses of durable animal earths, having only a comparatively small admixture of foreign mineral matter.

Cases, indeed, sometimes occur of soft animal matter being mineralized. Thus a silicefied oyster in the centre of the shell is described by VON BUCH; and Lord GREENOCK informs me that he possesses another similar fossil; but such instances are admitted by naturalists to be comparatively very rare.

Amongst all the fossil remains of Burdiehouse which have been the subject of these remarks, the phosphate of lime is preserved as the standard of comparison; and we have every reason to believe that whatever changes may have occurred in the nature or proportions of the other constituents, this one continues firm and invariable. Well, therefore, might it be called by Dr

BUCKLAND, the imperishable phosphate of lime. It has survived the extinction of species and the wreck of formations, and now aids us, at the distance of countless ages, in our attempts to connect together the organized beings of periods separated from one another by so vast an interval.

In concluding for the present, I have only a single word to say as to the slight trace of perishable animal matter which pervades all these remains. As we know that they all contain bituminous matter, and that many kinds of common coal yield ammonia by distillation, I thought it possible that the alkaline reaction of the limestone and of the various remains when heated, might arise from the bituminous matter. But on making some comparative trials between them and the coal used at the Glasgow Gas-Works, which yields an ammoniacal liquid on distillation, I found the alkaline reaction of the Burdiehouse remains was so much more decided than that of the coal, that there can be no doubt it arises from animal matter.* The strong ammoniacal reaction of the limestone, when subjected to heat, surpassing that even of the bones and scales, is remarkable, and shews how large a quantity of decayed animal matter from the various organic remains which have been entombed in it, has been diffused through its mass. In this respect, as well as in the character and extraordinary number of its fossil relics, both vegetable and animal, the subject of the interesting discovery of Dr HIBBERT is distinguished in a marked manner from the ordinary encrinal mountain limestone of the vicinity, which contains only a comparatively slight trace of animal matter.

* Indeed, in the way in which these experiments were made, which was by heating portions of the substances under examination in glass tubes, and observing the effect on turmeric paper, it is difficult to notice a proper ammoniacal reaction from the coal; whilst with the substances from Burdiehouse, particularly the limestone and coprolites, the alkaline reaction is observed with great readiness. In all such experiments it is easy to distinguish the *permanent* browning effect which the bituminous vapour exerts on the paper at a high temperature, from the true ammoniacal discoloration.

Hibbert-Ware, Samuel

On the fresh-water Limestone of Burdiehouse in the neighbourhood of
Edinburgh

Edinburgh 1835

4 Lith. 79 m

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